Product Development for Bovine Fecal Sampling and Canine Continence Care

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ABSTRACT

A key task in animal parasitology studies is the collection of faeces for analysis. In this project, a new device was developed. Anti-ballistic textiles were chosen for their tenacity and durability. Testing to international standards was undertaken to ensure suitability for animal use.

The new product, launched in June 2017, was markedly different from the harness system previously used and reduced the fitting difficulties for animal care staff and discomfort for the animals. The key challenges tackled in its development were ensuring a good secure fit, taking account of sensitive areas on the animal's body as well as the ease of positioning and removal of the collection device for staff. Unique design features were introduced to ensure comfort for the animal, and flexibility and longevity of the product, enabling the device to be fitted to animals of different ages and sizes.

To facilitate full development of the bovine product the researcher worked in collaboration with Moredun Research Institute, who were able to give feedback on the functionality of the product. The researcher also collaborated with the manufacturer J&D Wilkie, who produced the prototypes and subsequent revisions.

As a result of the design and development work on the bovine product, an additional simplified product to manage canine incontinence and sampling was also created. The design of both products was optimised for efficient manufacture and the production process and cost were considered at every stage of design development.

Acknowledgements

My grateful thanks to Dr Lisa Macintyre, whose encyclopaedic knowledge of textiles and experience in research made my work under her supervision a joy.

My thanks also go to Sarah Thomson at Moredun, whose excellent feedback on each new version of the calf product drove further development.

Finally to Bob and Kate, Ann and Dot, the production team at J&D Wilkie who brought my design and each subsequent improvement to life.

HERIOT WATT UNIVERSITY

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GLOSSARY

Anatomy	The body structure
Aseptic	Without contamination from micro-organisms
Bovine	About or relating to cattle
Continence	Control of the bladder and bowel
Durability	Being able to withstand repeated use
Fecal	Faeces, body waste expelled from the bowels
Fillet strap	Strap that passes round the hind legs to hold an animal rug in place
Hydrocolloid	A biodegradable adhesive dressing
Micro-organisms	Bacteria, fungi, viruses or parasites
Molle	Modular lightweight load carrying equipment. Rows of strapping to which equipment can be attached. Common in military clothing
Roping	A seam which has a twisted appearance
Rug	An animal coat
Surcingle	A clasp fastener with interlocking parts
Tactile	Touch and feel
Tenacity	Strength and resistance to breaking
Zoonotic	An animal disease that can also infect humans

CHAPTER 1 – INTRODUCTION

1.1 Project Introduction

Textiles have many applications. Other than clothing, textiles can be used to resolve problems and challenges in many settings. This research aimed to look at the issues associated with collecting faeces primarily from bovine [1] and secondarily from canine subjects [2], and to develop suitable collection devices. The project considered the reasons for collection and current methods in use were evaluated [3,4,5]. No commercially available collection product existed for bovine fecal collection, but as the design requirements favoured developing a calf jacket on which to secure a collection bag, and calf jackets were available, then the commercial products [6] were assessed for their suitability for modification. The design and construction of ethically acceptable collection devices and their commercial viability were explored.

The project team included the author, a research student from Heriot-Watt University School of Textiles and Design, supervised by Dr Lisa Macintyre who devised the project brief (appendix 1) and whose skill, knowledge and expertise in textile applications, research and testing enhanced the design and trials of the two developed products. Fiona Kenyon and Sarah Thomson at The Moredun Research Institute [7], an animal research organisation, would trial the bovine product, and Bob Low and his production team at J&D Wilkie, a Scottish textile and product manufacturer based in Kirriemuir, Angus [8], whose expertise in the manufacture of anti-ballistic garments, would offer access to specialist fabrics and industrial manufacture of the designed products.

1.1.1 The Bovine Bumbag

The bovine bumbag project would develop a product that collected faeces from calves, with greater functionality, better fit and more ease of use than the harness that was already being used and which had a number of issues that had to be addressed. Bovine faeces are collected for many reasons; the primary concerns of researchers include the measurement of parasitic load, the extent of the presence and prevalence of bacterial and viral organisms and the absorption of nutrients from naturally occurring and manufactured feedstuffs [3]. Added to the unpredictable nature of livestock is the exposure to potentially harmful micro-organisms that are equally as infectious in humans as they are in animals [9]. Protection from exposure was a key consideration in the development of both the bovine and the canine product.

The textile manufacturer, J&D Wilkie, provided suitable textiles and production methods to manufacture the first working prototypes and further revisions of the manufactured article until the final bovine product was agreed. This input ensured that the very best available hard wearing fabrics were made available for the project and that the manufacturing process could be optimised by the involvement of their manufacturing production team. Having access to these materials and facilities ensured that the commercial viability of both end products was continually to the fore.

It was vital to identify the current issues with the existing harness used and to negate those through better design, ease of use and better functionality. It was also necessary to develop a working knowledge of the key pathogens, particularly those that can lead to zoonotic infection [10,11,12]. An understanding of their transmission routes to humans and methods of control and removal would serve to indicate cleaning and disinfection requirements for the products being developed.

1.1.2 The Canine Product

The canine product was a follow on product, to be created building on the research for the bovine device. The canine product would have to have sound commercial viability in order to maximise the possible financial return from the research undertaken. An understanding of issues around managing canine continence and discussion with a veterinary practitioner and animal shelter manager offered a better knowledge base on which to develop the canine device.

1.2 Aims and Objectives of the Project

The aims of the project were to:

> Develop and test novel products for the hygienic collection of faeces from calves and to develop and test novel products for the hygienic collection of faeces from dogs.

The objectives of the research were:

Design improved harness/garment systems to support faeces collection bags. Design 2 layer faeces collection bag system with ‘water’ proof seals and easy/hygienic removal of inner bag. To source suitable materials for all elements of designs. Manufacture and evaluate prototype systems. Develop optimised prototypes and final design of a complete faeces collection system for calves. Consult with vets, dog owners and others involved in dog care to establish design criteria for a faeces collection system for dogs. Develop first prototypes of a faeces collection system for dogs. Publicise new products.

1.3 Thesis Outline

Chapter 2

Present a review of the literature surrounding bovine fecal sampling, zoonoses, canine continence, fabric selection, an evaluation of human waste collection products and worldwide patents for existing products developed for the collection of dog faeces.

Chapter 3

Identifies suitable materials and the testing methods used to evaluate their suitability for use for the bovine product.

Chapter 4

Reports on the test results and discusses the outcomes of testing and how this contributed to further product optimisation.

Chapter 5

Describes the product development phase, through design evaluation with Moredun research institute who gave access to undertake product wear trials and J&D Wilkie who took the design specifications and manufactured the prototypes and subsequent revisions until the final product was launched.

Chapter 6

Outlines the development of the canine product, building on the bovine research that had already been undertaken.

Chapter 7

Offers a project conclusion as well as identifying opportunities for further research and development.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

This research project planned to develop two products. A ‘bovine bumbag’ used to collect faeces samples from calves and required by animal research organisations, as a commercially available device does not currently exist. A canine product would then also be developed, building on the bovine research carried out with a view to developing a professional quality incontinence and hygiene management product for dogs, to be retailed through veterinary surgeries.

A literature review was carried out to determine contributing factors to the development of both products. Five distinct subject areas were evaluated:

- Bovine fecal sampling
- Zoonoses
- Canine continence and existing hygiene products
- Human waste collection products
- Patents relevant to the dog product

2.2 Bovine Fecal Sampling

Prior to working on the design of a bovine fecal collection product, it was necessary to establish an understanding of the different methods that are used to obtain fecal samples. As faeces are a waste product, it was important to understand the pathogens that are present in the samples that the product is being designed to collect. It is also vital to understand how humans can be affected by contact with the pathogens present in order to consider reduction of exposure in the product design.

2.2.1 Sample Collection in the Past

In the past a leather harness could be used to attach a nylon and plastic collection bag. Research by Hughes [1] in 1962 illustrates this, this ensured the total collection of all faeces and urine produced in the test animal and is shown in Figure 2.1.

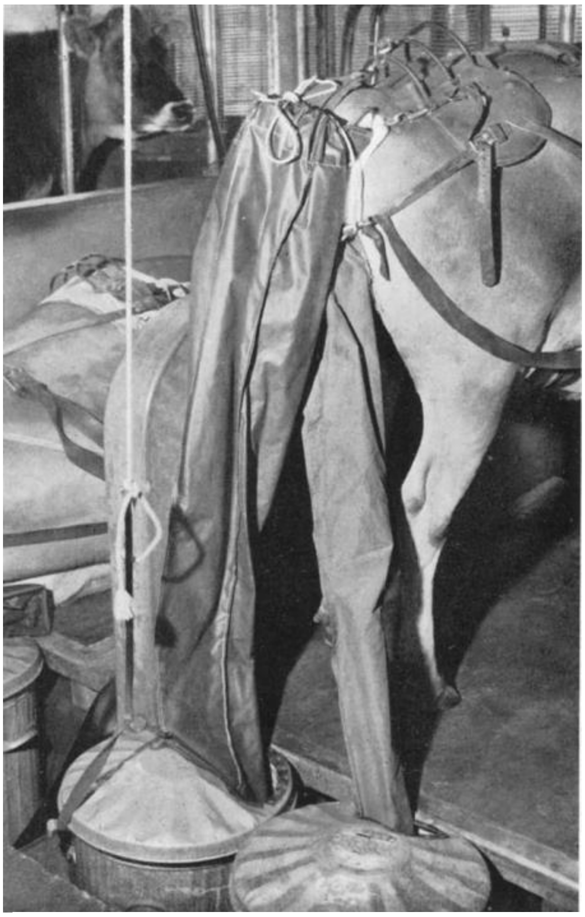


Figure 2.1 collection harness 1962 [1]

There are a number of observations about this set-up that would make its use inappropriate today. This method required the animal to be largely immobile, standing in a stall for the duration of the collection. It is now considered kinder to not keep animals tethered and today the ethical standards around the use of animals used for experimentation have changed significantly; current animals (scientific procedures) act (ASPA) guidelines suggest that animals are only used when any other possible alternative methods of testing have been considered [13]. The 1962 harness was used for adult cattle, however the device being developed in this project is to be worn by calves in the early weeks of their lives as shown in Appendix 1. The marked reduction in the use of animals in testing has reduced the marketability of specialist test related products. Nevertheless there is still the need for a bovine collection product to be developed. This small specialized market may have contributed to the lack of a commercially available product for research establishments to use. Six decades after the harness Hughes [1], mentioned was utilised, there is a greater understanding of the organisms present [14], how they can passed on [15], and how to control and prevent cross contamination and infection [16].

2.2.2 Fecal Sampling Collection Methods

It is beneficial at this point to consider the methods used to collect bovine fecal samples. By understanding the different methods, their advantages and disadvantages, it is possible to understand better why a collection device is necessary to collect whole samples of faeces over a given amount of time. Although the use of a harness to assist collection may be mentioned as by Rinne et al [17], no detailed information about the design, fit, hygienic cleaning and effectiveness of the harness is provided at all.

Many research articles though, do indicate the methods used to collect fecal samples and it would appear that much depends on the type of research being carried out and / or the type of organism, bacteria, parasite or other that is being studied. It is suggested that a direct rectal sample of faeces is taken for parasitological testing [5], however a number of different methods are identified in recent research. In testing for E.Coli 0157 for example, fecal samples were collected from the floor of the pen of individual animals [18]. A more recent E.Coli investigation combined individual rectal samples and combined, pooled samples, collected from the floor of a pen containing 10 animals [19]. Further insight into fecal sampling was offered by Lombard et al, [3] who describe three methods of collection;

- **Composite Samples** come from a number of animals housed together and whose faeces have been produced over a number of hours. The sample is taken from several locations in pens, alleyways or manure collection grids.

- **Individual Samples** are normally taken, and results in a small amount of faeces being collected directly from the rectum of the animal. This is time consuming and costly, each animal requiring its own container and the person carrying out the sampling has to change gloves between animals. This gives only a small sample and is made more problematic if the animal has diarrhoea as the sample is collected by hand.

- **Pooled Samples** are collected usually from the floor of the individual pen of a single animal and may come from several fecal deposits in the pen.

The study completed by Lombard et al [3] compared testing of individual, pooled and composite fecal samples and concluded in some cases that composite sampling, which is cheaper to undertake, gives similar results to individual sampling. Whilst this research would indicate that in some animal testing, collecting a composite sample adequately detects the presence or prevalence of some diseases or parasite burden in a herd, more detailed research that requires a complete sample of all faeces produced by an animal for analysis without being contaminated, requires a better means of collecting a whole sample over a given time period.

It is reasonable to suggest then, that currently, to collect an individual, whole, pooled sample, an animal would have to be housed in a pen with no bedding to enable its faeces to be collected from the floor of its pen. That animal would stand, or lie, in its own faeces over a number of hours. A sample collected in this way would still be open to contamination from the air, flies, vermin, urine or the floor itself. Given the opportunities for a sample to be contaminated, it is surprisingly still considered acceptable, that where an individual sample cannot be obtained, samples can be collected from the ground [4].

2.3 Zoonoses

"Zoonoses are diseases and infections that can be passed from animals to humans. All animals naturally carry a range of micro-organisms, some of which can be transmitted to humans, where they may cause ill health, which in some cases may be severe or life threatening…" [9]

It is important to identify those zoonoses that are commonly found, the means of transfer and to also examine how exposure to the organisms can be managed. Organisms can be viral, bacterial, fungal, parasitic or protozoan, and Table 2.1 shows the commonly occurring zoonotic organisms commonly found in the UK [20].

Some common causes of disease in humans			
Viruses	DNA Viruses	Adenoviruses	Human adenoviruses (e.g., types3,4,and 7
		Herpesviruses	Herpes simplex, varicella zoster, Epstein-Barr virus, cytomegalovirus, Kaposi's sarcoma
		Poxviruses	Vaccinia virus
		Parvoviruses	Human parvovirus
		Papovaviruses	Papilloma virus
		Hepadnaviruses	Hepatitis B virus
	RNA Viruses	Orthomyxoviruses	Influenza virus
		Paramyxoviruses	Mumps, measles, respiratory syncytial virus
		Coronaviruses	Common cold viruses
		Picomaviruses	Polio, coxsackie, Hepatitis A, rhinovirus
		Reoviruses	Rotavirus, reovirus
		Togaviruses	Rubella, arthropod-borne encephalitis
		Flaviviruses	Arthropod-borne viruses, (yellow fever, dengue fever)
		Arenaviruses	Lymphocytic choriomeningitis, Lassa fever
		Rhabdoviruses	Rabies
		Retroviruses	Human T-cell leukaemia virus, HIV
Bacteria	Gram +ve cocci	Staphylococci	Staphylococcus aureus
		Streptococci	Streptococcus pneumonia, S, pyogenes
	Gram –ve cocci	Neisseriae	Neisseriae gonorrhoeeae, N. meningitides
	Gram +ve bacilli		Corynebacteria, Bacillus anthracis, Listeria monocytogenes
	Gram –ve bacilli		Salmonella, Shigella, Campylobacter, Vibrio, Yersinia, Pasteurelia, Pseudomonas, Brucella, Haemophilus, Legionella, Bordetella.
	Anaerobic bacteria	Clostridia	Clostridium Tetani, C. Botulinium, C. perfringens
	Spirochetes		Treponema pallidum, Borrelia burgdorfen, Leptospira interrogans
	Mycobacteria		Mycobacterium tuberculosis, M. leprae, M. avium
	Rickettsias		Rickettsia prowazeki
	Chlamydias		Chlamidia trachomatis
	Mycoplasmas		Mycoplasma pneumoniae
Fungi			Candida albicans, Cryptococcus neoformans, Aspergillus, Histoplasma capsulatum, Coccidiaides immitis, Pneumocystis carinii
Protozoa			Entamoeba hystolytica, Giardia, Leishmania, Plasmodium, Trypanosoma, Toxoplasma gondii, Cryptosporidium
Worms	Intestinal		Trichuris tricura, trichinella spiralis, Enterobius vermicularis, Ascaris lumbricoides, Ancylostoma, Strongyloides
	Tissues		Filaria, Onchocerca volvulus, Loa loa, Dracuncula medinensis
	Blood, liver		Scistosoma, Clonorchis sinesis

Table 2.1 Common zoonotic organisms in the UK [20]

2.3.1 Zoonotic Organisms and Disease

Zoonoses are important to consider as the products being developed through the project will collect faeces. Faeces can harbour disease and illness-causing organisms. There are presently 40 identified zoonoses prevalent in the UK [10]. Whilst workers have a degree of protection from the existing health and safety legislation, pet owners and the public in general may have very little awareness of the likelihood of picking up disease or infection from their pets, even though it has been known for some time that domestic pets pose a significant health hazard [2].

It has been estimated that the majority of infectious diseases are a result of zoonotic organisms [11]. An American study by Hale et al [12], suggested that 14% of all illnesses in the US were caused by the seven most common pathogens passed on through animal contact. Whilst the dramatic diseases e.g. Rabies, Anthrax, Ebola, HIV, and Creutzfeld Jacob Disease – CJD (also known as mad cow disease) may attract media attention, commonly occurring pathogens such as E.Coli and Salmonella and many other pathogens with zoonotic origin are estimated in a publication by The Lancet, The Lancet: Zoonoses: Global Health Series [11], to cause around 1 billion illnesses globally and many millions of deaths annually.

2.3.2. Exposure in the Workplace

As the bovine product being developed will be used in research organisations, the risk of zoonotic infection is managed through two pieces of health and safety legislation; Control of Substances Hazardous to Health 1994, (COSHH) [16] and Management of health and safety at Work Act 1992 (MHSAW) [21].

The health and safety executive (HSE) investigates occupational exposure that can be linked to chronic ill health. In a workplace setting such as in a research establishment where the bovine product will be used, health surveillance can test staff for exposure to and infection from zoonotic organisms as this comes under the legislative requirements of COSHH and MHASAW.

Although HSE guidelines are intended for use in the workplace, they offer sensible advice for pet owners in how to control and manage exposure to infective organisms. There is currently no available guidance for pet owners in either promoting awareness of zoonotic organisms or in the management and control of exposure.

2.3.3. Exposure to Pet Owners

In healthy dogs it is suggested that there is a 15% risk of picking up a zoonotic pathogen, however this is in a healthy pet. It might be reasonable to expect that a sick pet will be handled and/or petted more so this risk will increase [22]. Overall it is accepted that there is a lack of research in infection control in pets [23,24]. It might be prudent for veterinary surgeons to play a bigger role in educating the public [25], but perhaps manufacturers of pet products should also take some responsibility. In developing the bovine and canine products, this project would have to make every effort to ensure that proper instruction was given in the use, cleaning and disposal of the proposed products to reduce as far as possible any risk of contamination of fecal matter to research staff or dog owners and their family.

2.3.4. Canine Continence and Pet Products

No credible academic articles were found whilst researching issues around canine continence. It was necessary to refer to magazines, blogs and websites to establish the scale of the problem and the current methods used by dog owners to manage incontinence. It was necessary to explore this subject to identify the best market in which to place the canine product and also to evaluate as objectively as possible the availability and functionality of existing continence care products being retailed. Peripheral subjects like dog welfare [26], end of life care for dogs [25], and ill health from animal contact [10], were studied to find out whether any legislative framework existed for dog owners and whether there were any further sources of information on continence management.

The code of practice for the welfare of dogs [26] advises dog owners on the animal welfare act of 2006 and how to make decisions about the care of their pet. The guide does observe that dogs will not soil their living area and need access to a toilet area and that those which are very young, old or unwell may toilet more frequently. It also suggests that the dog should have a “safe, clean environment” [27].

2.3.5 The market for the Dog Product

The pet food manufacturers association estimate that there are over 8 million dogs kept as pets in the UK with an average life expectancy of ten years, with the commonly owned pedigree breeds varying in size from the Chihuahua to the German shepherd [28]. A previous study estimated dog ownership to be closer to ten million [29]. As micro chipping became compulsory in April 2016 [30], it may offer a more accurate assessment of the dog population this in turn will indicate the size of the potential market for the dog product being developed. The term "pet owner as parent" is used in a Mintel market report [31], to describe pet owners who treat their pets as 'children' and further suggests that pet friendly care products are a growing market The report also includes research that shows, summarised in table 2.2, almost half of all pet owners to be concerned about "picking up germs from pets or areas that have had contact with pets"

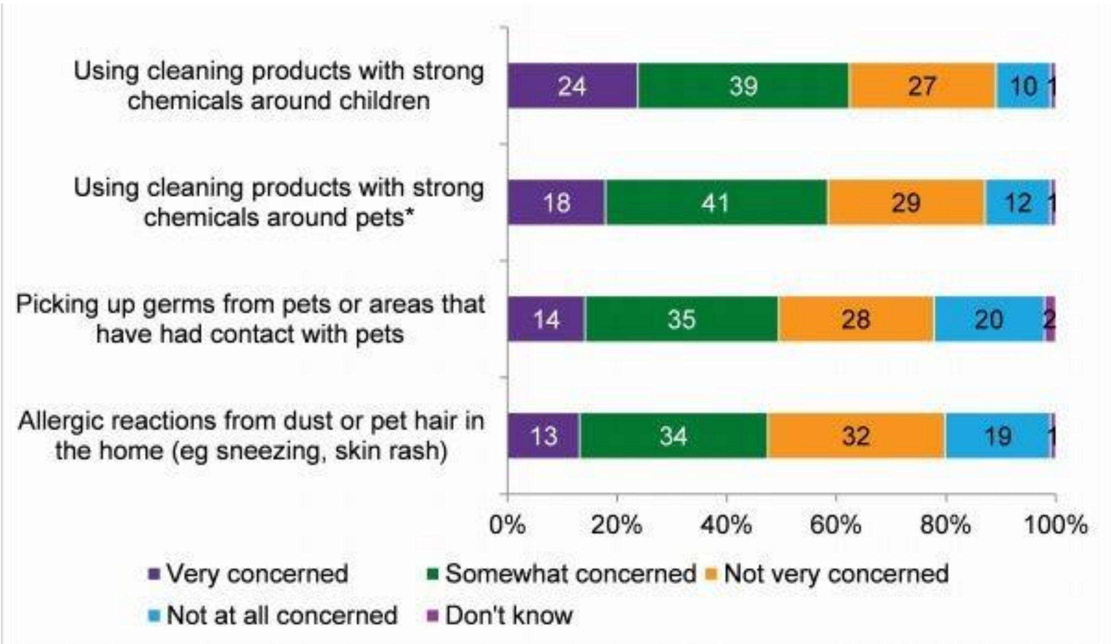


Table 2.2 Mintel, (2015) 'Big opportunity for pet care within household care'[31]

2.3.6 Dog Incontinence

Many articles cover only urinary incontinence. Advice tends to suggest that medication or surgery will resolve the problem [32,33]. Other articles discuss the causes of incontinence. No articles were found that offered advice on the use of currently available products, yet pet shops and online pet supplies stores offer dog nappies [34], shown in Figure 2.2, and various types of harness [35],that claim to address the problem.

Figure 2.2 Dog nappy

Dog owners are recommended to lay layers of towels and blankets to absorb soiling in several places throughout the home [36]. This advice would give the pet owner a large amount of washing to cope with daily. When giving end of life care, the dog owner generally wants to provide care at home [37], yet there are no professional continence care products available with veterinary commendation. Increasingly, a quality of life assessment questionnaire is being used by many vets to help owners manage declining health in elderly pets or those with life limiting illnesses [38]. In end of life care it is interesting to note that although quality of life addresses hygiene, it only suggests that the animal "should be brushed and cleaned, particularly after elimination" [39], it doesn't ask the owner whether they can cope with managing continence. As dog soiling is a common vector for infection being passed to humans [40] it is clear that there is a market for a veterinary endorsed canine hygiene product range. Those products should be made as safe and hygienic for the dog owner to use, with clear instructions, so as not to put them at any further risk of infection.

2.4 Human Waste Collection Products

As products for the collection of human waste are available, it is worth considering if they can be used, or modified for use, for either the bovine or the canine product.

2.4.1 Human Waste Collection

There are two main types of human waste collection product. The first collects urine from a fine tube, a catheter, placed inside the bladder and extending to outside the body [41, 42]. A variety of bags are then attached by a serrated terminal end inserted into the tube. These bags can be drainable by means of a push valve or lever tap as shown in Figure 2.3, or they can be single use.

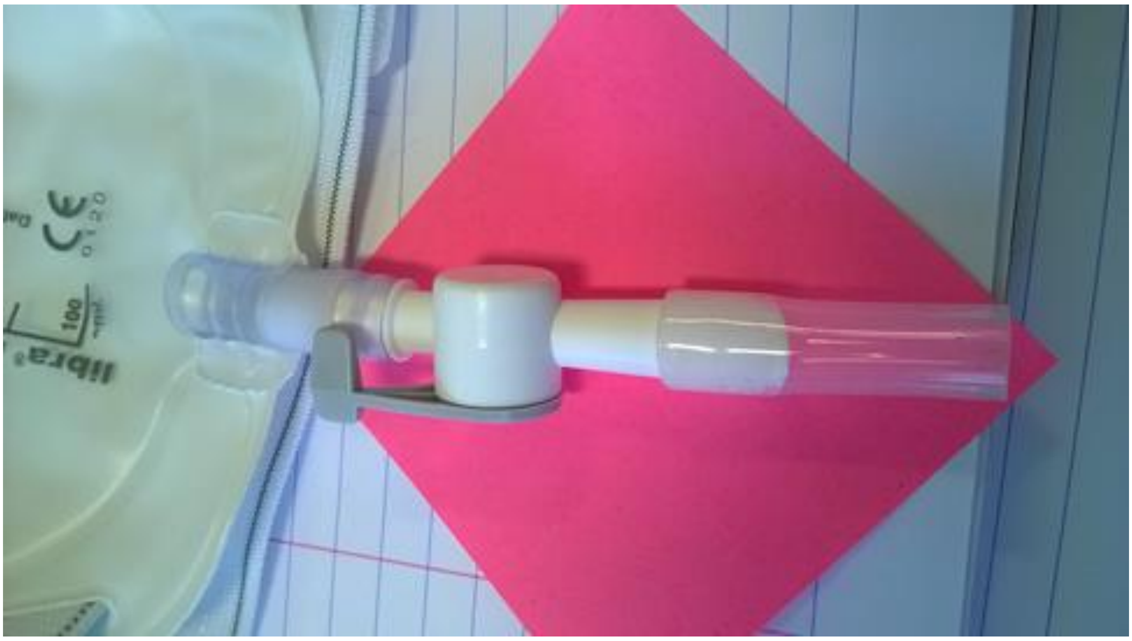


Figure 2.3 lever tap on catheter bag.

They are used in both the home and in acute medical settings like hospitals. In use they have to contain urine without spillage and changed and emptied in an aseptic way that negates risk to either the patient or staff member from spillage and contamination. Catheterisation is used in a number of different ways;

- Incontinence
- Critical patient management

- Surgery
- Human solid waste

There are two main products for collecting human solid waste. Both are used in cases where the person has their bowel resected, due to illness or disease, and an opening formed in their abdomen from which the bowel contents are emptied. As this function is no longer voluntary the patient has to cover the opening with a collection device that has to contain the bowel contents as they are discharged. They have a valve that allows the release of gas. An odour control filter also included.

Ileostomy bags collect waste from the small intestine whose contents are liquid, and a colostomy bag collects waste from the large intestine, whose contents can be semi-solid. The bags used come in different sizes, some are single use and others are drainable. Most are stuck onto the skin with a flexible hydrocolloid adhesive part that is either part of the collection bag; a one-piece bag, or it may be separate; a two-piece bag [41, 42]. The two-piece product allows bags to be changed many times before the part adhered to the skin needs to be removed. These products can offer the project either a ready-made solution to collecting animal waste or can act as a sample to be reproduced into an animal product. The key areas to investigate are the adhesive used and whether it will be suitable for animal use and to look at alternative methods of adhesion if necessary.

2.5 Patents.

To ensure that the dog product was a unique design a patent search was carried out using the European patent search portal Espacenet [43]. This site gives access to global patents and patent applications. Various search terms were tried with limited success so finally a general search under 'dog' was carried out. This returned over 10,000 entries so various key phrases were tried like 'dog waste' and 'dog waste collection' until finally a keyword tool was used [44] that suggested that 'dog excrement' would be the key phrase to search for. The keyword tool is used by website builders to ensure search engine optimisation (SEO), and lists the most common words or phrases used in internet searches. A comprehensive overview of all past and present patents was undertaken. From an initial search result of 570. 463 patents were discarded due to obviously being not concerned with the direct collection of faeces from the animal, leaving a shortlist of 107 patents to look at in detail. The 107 shortlisted patents were further reduced when looked at in detail. The initial search results contained many ambiguous titles and terms that required the whole document to be consulted. Only those containing a clear description and/or a detailed drawing that indicated direct collection of faeces from the dog were looked at in detail. The final number of relevant patents therefore that were fully read was 13 [45 – 57].

2.5.1 Patents Relevant to the Development of the Dog Product

Some patents showed designs that were very complex, Eberle [45] in Figure 2.4 for example has designed a product with 78 design features. This amount of detail would result in an expensive product. There were many designs that relied on a significant harness structure to secure a collection bag to the anal area [46,47,48,49] Some designs involved a rigid frame to be fitted around the anal area [50,51,52], these may cause discomfort to the animal. Two designs relied on the tail as a fixing point [53,54,55,], these may easily slip from position depending on the animal's coat and the tail structure itself, considering that tails have a wide range of movement. Brooks [56] and Gerard [57] patented fairly simple harnesses, shown in Figure 2.5, but these are secured around a part of the dog's abdomen that has no natural 'waist' anatomy to hold the indicated strap in place. On both designs, the collection bag attachment failed to take account of the anatomical curve of the hindquarters.

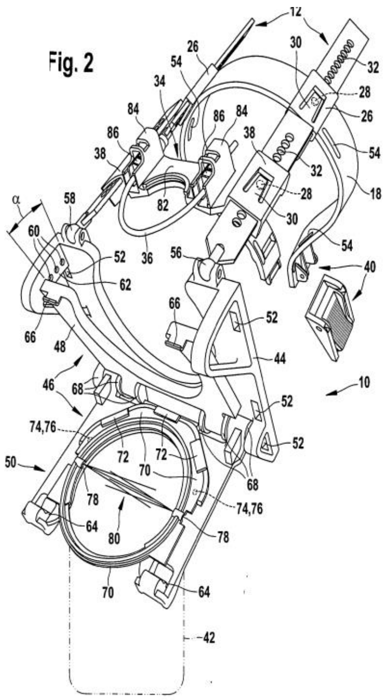


Fig 2.4 Helmut Eberle (2006), [62]

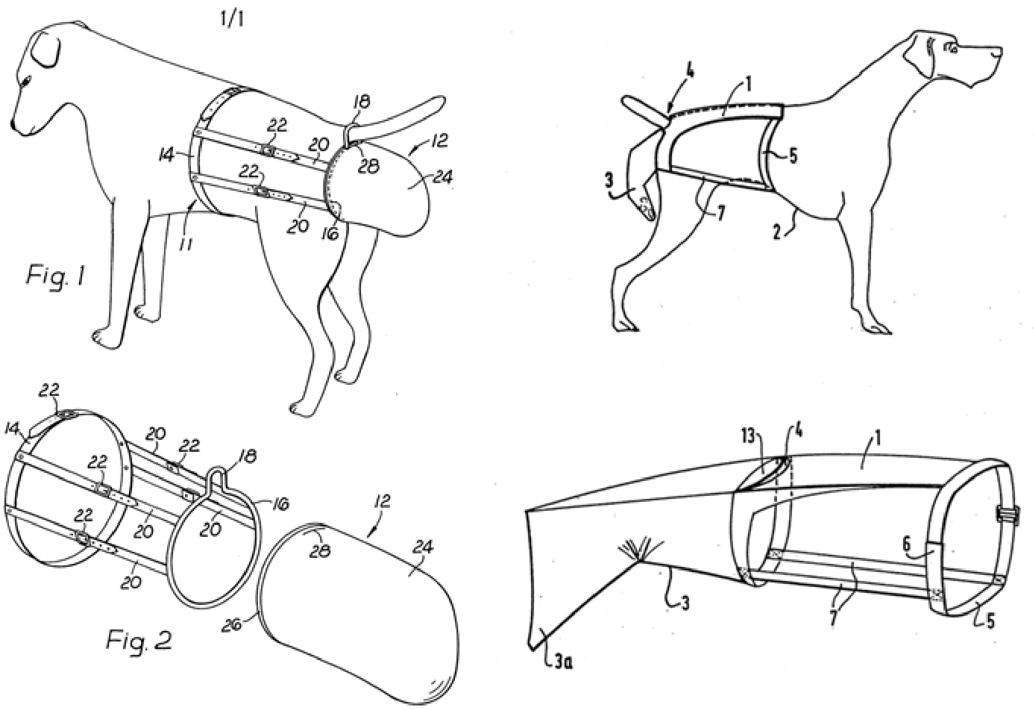


Fig 2.5 Florence Brooks, (1985) [59] left and Andree Gerard, (1991) [60] right

The patent search offered many designs but few were simple products. It is important in designing a product to go to market that it is kept as simple as possible. This ensures that costs can be kept low and offer a good return or profit for the manufacturer but also this ensures that it is easy for the dog owner to use. Many of the patents evaluated, did not appear to have considered the amount of skill needed by the person who would have to fit the device.

2.6 Textile wash care

Care of the textiles chosen, particularly washing was considered important. The reason being, that an organism common in bovine hosts and less so but still possible in canines is Cryptosporidium. This is a protozoan parasite that can be passed on through contact with the animal itself, its faeces or infected water [15]. This parasite is resistant to all commonly available disinfectants including bleach [58], therefore, using an antibacterial washing powder at its recommended wash temperature of 40°C, means that the organism will not be destroyed from animal clothing or bedding. Many pet products used to protect furnishings give no advice on laundering. Additionally, such products are often found to be made of fabrics that would not withstand washing at a temperature hot enough to kill commonly occurring pathogens. This is shown on Figure 2.6 in a selection of wash care labels from dog textile bedding products.

Figure 2.6 Wash care labels from a selection of dog textile bedding products

Wash temperature is important as the normal body temperature of cattle is 38.5°C [59] and in dogs it is between 37.8°C and 39.2°C [60]. A wash cycle of 30°C is below normal body temperature for these animals, and it might reasonably be presumed that this temperature will not kill micro-organisms that survive on their animal hosts, and that even a 40°C wash may be ineffective at eradicating the majority of pathogens [61].

It is very important when developing a textile based animal product that consideration is given to the lack of knowledge of animal care staff and pet owners of both the risk of infection from contaminated textiles and infection control by adequate laundering [62,63]. The products being developed in this project must be washable at temperatures that will kill infective pathogens and adequate wash care instructions must be given. To ensure that all common pathogens are taken care of for both the bovine and canine product a textile must be chosen that can withstand laundering at over 90°C. It is known that natural fibres like cotton and linen can withstand laundering at high temperatures [64] but their absorbency leads to longer drying times. Man-made fibres/filaments are often cheaper, and because they are less absorbent they dry quicker. However, man-made fibres including natural and synthetic polymers have to be laundered at lower temperatures, generally between 30°C and 60°C [65] and further to this, in a fabric that is a blend of fibres it is necessary to wash that fabric at the highest temperature of the most sensitive fibre. The guidelines for washing contaminated linen in hospital and care settings suggests efficacy at 65°C for 10 minutes or 71°C for over 3 minutes [66] however there is growing evidence that some nosocomial infections and diseases come from laundered linen, [67,68,69,41].

CHAPTER 3 - MATERIALS AND METHODS

3.1 Materials

A key consideration in the choice of appropriate fabrics for the products being developed in the project, and discussed in chapter 2.6, was their ability to withstand high temperature laundering. They also had to be strong enough for animal use, and so a selection of tests were chosen to indicate their suitability.

3.2 Commercial Calf Jacket Testing

As part of the product development, a commercially available calf jacket was considered for modification. As only one make was available, Cosy Calf produced by cosycalf.co.uk [6], was tested. It was washed 10 times as described in to BS EN ISO 6330:2012 [77]. And then conditioned to BS EN ISO 139:2005 +A1:2011 [70]. Provided the garment washed well, samples would be taken from the outer fabric and the lining fabric and tested for maximum force and elongation to BS EN ISO 13934-1:2013 [71], tear strength to BS EN ISO 13937-3:2000 [72], and abrasion resistance to BS EN ISO 12947-2:1998 [76].

3.3 Textile Choice

Both products under development had to be affordable. As natural fibres are more absorbent and have a longer drying time, three man-made textiles were chosen to be tested for the bovine product:

- Texturised nylon

  A ballistic nylon fabric, made with filament yarns with a plain weave with a polyurethane coating. This is used in body armour and is a strong, durable fabric. The fabric is 19 ends and 17 picks per cm. Figure 3.2 shows face and reverse sides shown together on the left and at 5 x magnification on the right.

Figure 3.2 Texturised nylon, face and reverse sides, left, and x5 magnification, right.

- Polypropylene

  A more open weave than the Texturised nylon, but very hardwearing and commonly used for horse rugs. The fabric was also made from filament yarns in plain weave with 11 ends and 11 picks per cm. This fabric does not have a coating so looks the same on both sides and is shown in Fugure 3.3, with the fabric on the left and at 5x magnification on the right.

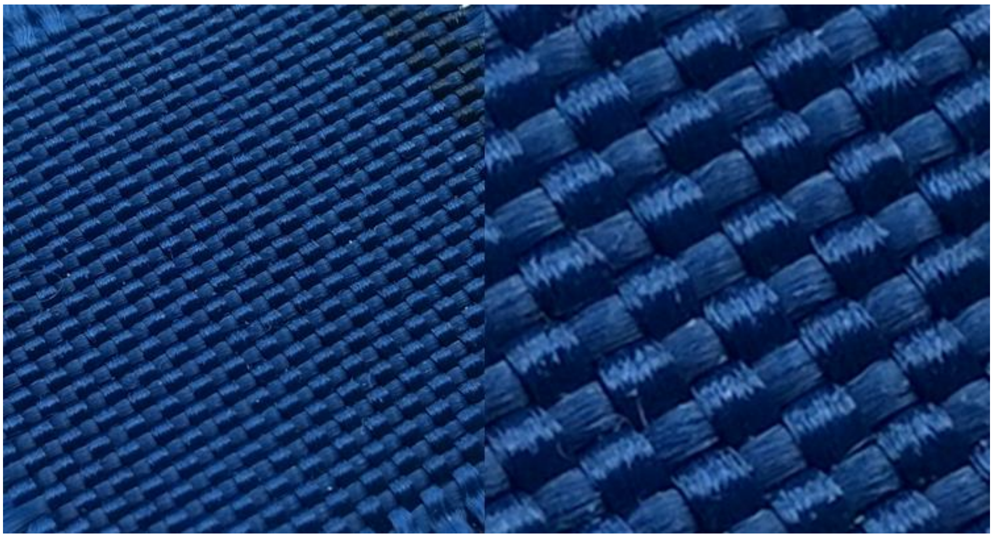


Figure 3.3 Polypropylene fabric, right, and at 5x magnification on the left.

- Nylon mesh spacer fabric

  A 3D mesh spacer fabric that could be used as a lining as it would allow the circulation of air between the garment and the animal's coat. This would ensure that the animals would not overheat. The fabric was warp knitted from filament yarns with 12 wales and 12 courses per cm. Figure 3.4 shows the reverse side on the left and the face side of the fabric on the right at 5x magnification.

Figure 3.4. 3D mesh spacer fabric at 5x magnification

- The commercial calf jacket fabrics would also be tested for comparison. The outer fabric was a rip-stop waterproof nylon fabric with 16 ends and 14 picks per cm as shown in Figure 3.5 at 5x magnification

Figure 3.5 Rip-stop nylon fabric

The lining was a plain woven polyester fabric with 48 ends and 34 picks per cm as shown in Figure 3.6 at 5x magnification.

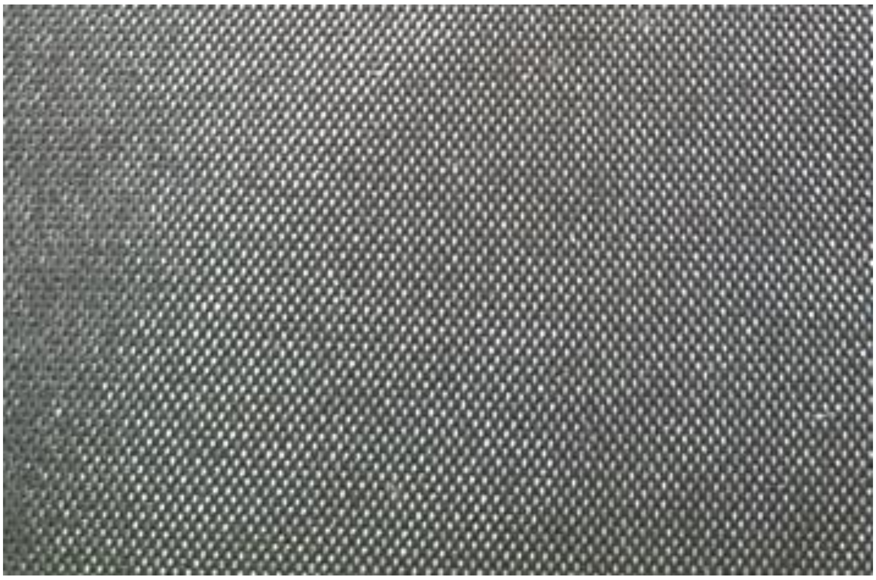


Figure 3.6 Polyester lining fabric

3.4 Testing Methods: Preparation of Unwashed Fabrics

Six tests were carried out to evaluate how the fabrics, and therefore the products made from them, would be affected by higher temperature washing. As a control, samples of the three fabrics would remain unwashed, and were prepared in accordance with BS EN ISO 139:2005 +A1:2011 [70], Textiles, Standard Atmospheres for Conditioning and Testing: The fabrics were laid flat out for 24 hours in a conditioned lab maintained at a standard temperature of 20 ± 2° Celsius and 65% ±5% relative humidity.

3.4.1 Maximum Force and Elongation

Maximum force and elongation to BS EN ISO 13934-1:2013 [71]. Woven samples were cut to 300mm long and 60mm wide. The 60 mm width was frayed down to 50mm. The warp knit samples were cut to 300mm long and 50mm wide. For each fabric 5 samples were cut in the warp and 5 samples cut in the weft. The gauge length was set at 200mm and rate of extension set at 100mm/min. An Instron DETAILS OF MACHINE HERE was used. Maximum force measures the amount of force in Newtons it takes to burst the fabric and elongation, also known as maximum extension is also measured which is the amount of distance in millimetres that the fabric stretches before bursting.

3.4.2 Tear Test

Determination of tear force of wing shaped test specimens was tested in accordance with BS EN ISO 13937-3:2000 [72]. Ten wing shaped samples of each fabric were used. Five samples from the weft direction and five samples from the warp direction were prepared for testing. The gauge length was set at 100mm and rate of extension set at 100mm/min. This test was chosen to evaluate whether high temperature washing weakened the fabric enough to make it rip or tear more easily. It was also carried out on unwashed samples to have a set of baseline data to compare with the results from the washed samples.

3.4.3 Dimensional Stability

BS EN ISO 3759:2011 [73], Textiles- Preparation, Marking and measuring of Fabric Specimens and Garments in Tests for determination of Dimensional Change. Three samples were taken from each fabric. A 500mm square was cut from the bottom left, centre and top right of the fabric. Each sample was marked with a contrasting thread. A 120 corespun polyester thread was used with a size 8 crewel needle to make 8 marks on each sample. Measurements were made using a calibrated metre rule

3.4.4 Wrinkle Recovery

One sample square, 500mm x 500mm, of texturised nylon fabric was stitched and bound to the mesh spacer fabric, and one sample square, 500mm x 500mm, of polypropylene fabric was stitched and bound to the mesh spacer fabric and evaluated using ATTCC test method 128 [74], scored from 5= smooth to 1= very wrinkled. The evaluations were carried out by 3 different people: the author of this report and two independent evaluators, one from the manufacturer, and one from the animal research institute.

3.4.5 Seam Pucker

One sample square, 500mm x 500mm, of texturised nylon fabric was stitched and bound with single turn polyester herringbone tape to the mesh spacer fabric, and one sample square, 500mm x 500mm, of polypropylene fabric was stitched and bound with single turn polyester herringbone tape to the mesh spacer fabric and evaluated using BS EN ISO 7770 [75], scored from 5 to 1 and shown in Figure 3.7.

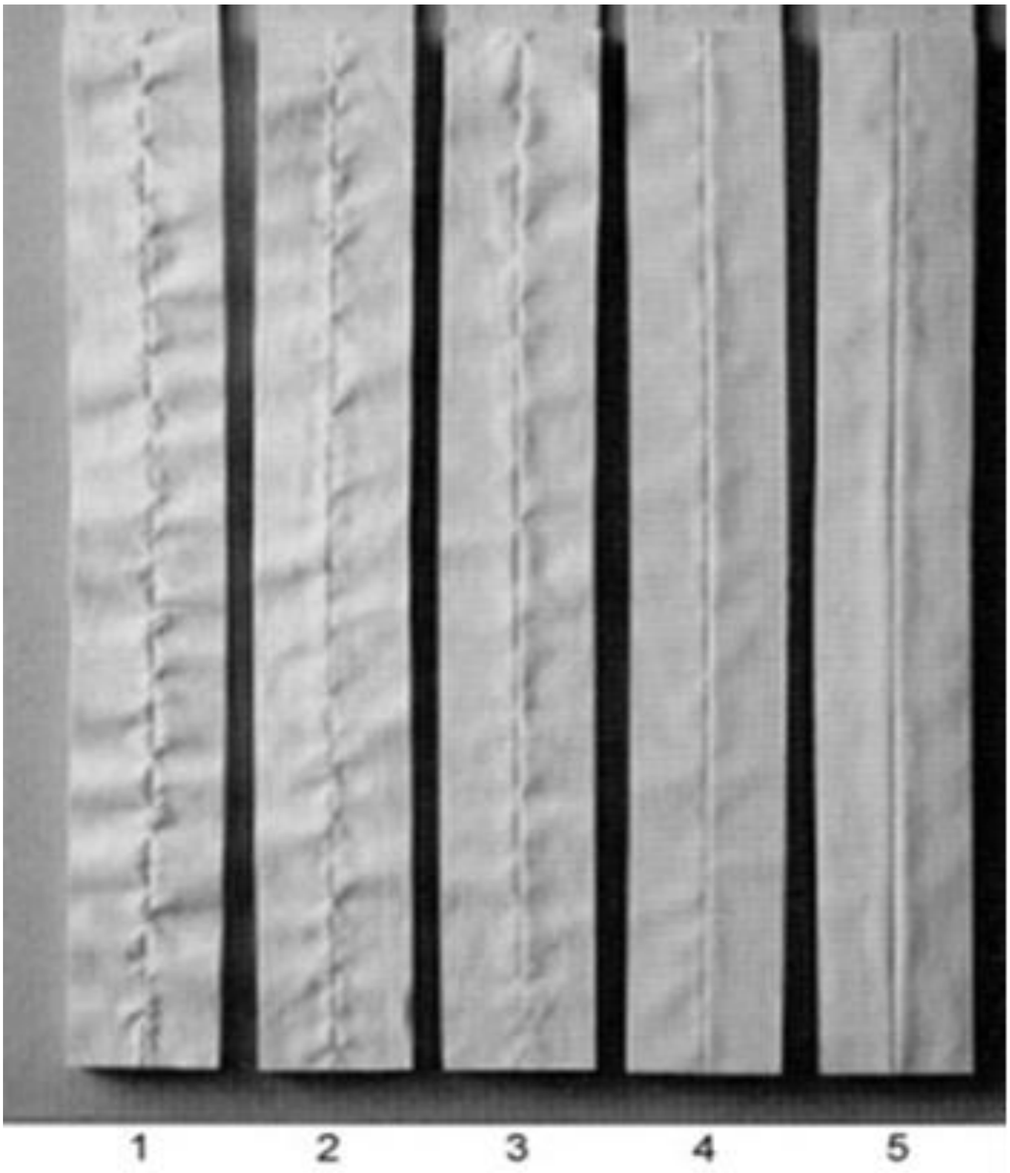


Figure 3.7 Seam pucker scale

3.4.6 Abrasion Resistance

Three samples were tested for abrasion resistance in accordance with BS EN ISO 12947-2:1998 [76]. They were tested on a Martindale abrasion and pilling test machine, using a 12 Kilopascal weight (795 ± 7 gms). The standard wool reference abradant fabric was used and this was changed every 50,000 test cycles.

3.4.7 Abrasion Resistance Test Intervals

All fabric samples were examined after 1,000 test cycles, then at 5,000 and 10,000 then every 10,000 test cycles. If the test samples showed signs of nearing break-down the test interval was reduced to 1,000 test cycles to gain as accurate a break-down point as possible.

3.5 Testing Method: Preparation for Post-Wash Testing

Six tests were carried out to evaluate how the fabrics, and therefore the products made from them, would be affected by higher temperature washing.

Nine, 50cm test squares were cut from each fabric. Figure 3.8, shows the fabric layout with the selvages on the right and left and an indication of where the nine test samples were cut from. Sets of three squares that didn't share the same warp or weft threads would be washed 1, 5 and 10 times and then tested. The 1 wash squares chosen were square nubers 1, 5 and 9. The 5 wash squares chosen were numbers 2, 6 and 7 and the 10 wash squares chosen were numbers 3, 4 and 8.

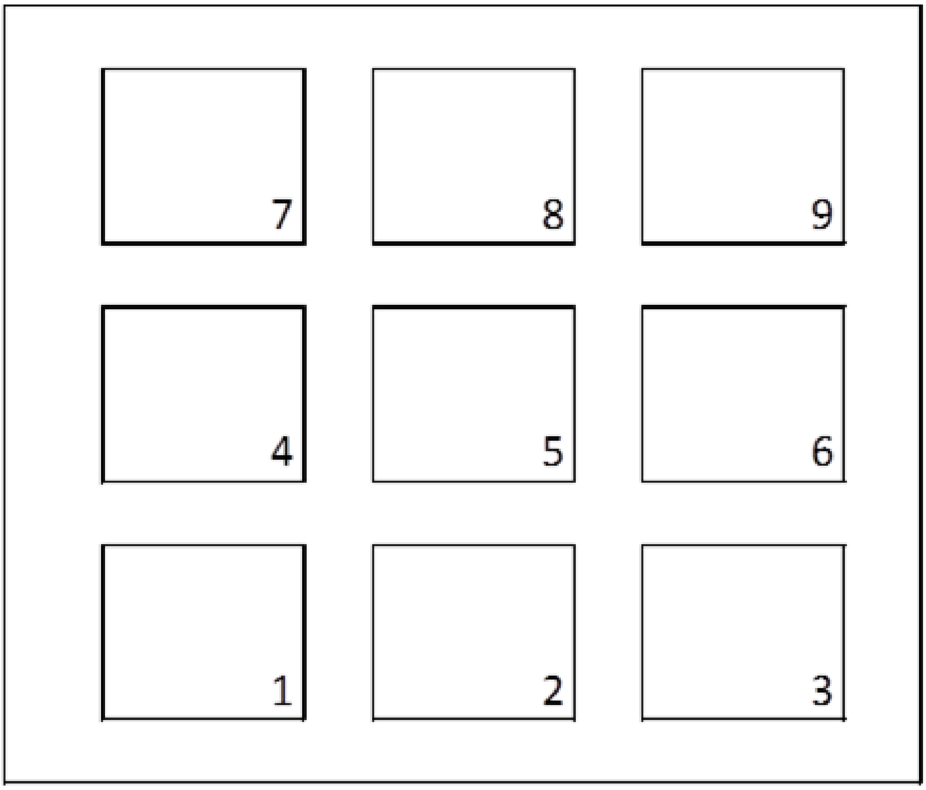


Figure 3.8 Fabric layout with test samples indicated

Wash Test

The wash test was carried out to BS EN ISO 6330:2012 [77]. The machine used was a Type A, horizontal axis, front loading British Standard machine. The samples were air-dried flat on a metal drying rack. The ballast used to make the wash load up to the regulatory 2 kg was woven polyester and the detergent used was reference detergent 1. The samples were washed on a 92°C ±3 wash, being allowed to fully air dry between washes. Three samples (numbered as described above) were removed for testing after the first, fifth and tenth wash.

After washing and prior to testing, the fabrics were conditioned according to BS EN ISO 139:2005 +A1:2011, Textiles, Standard Atmospheres for Conditioning and Testing [70]. The fabrics were laid out flat for 24 hours in the conditioned lab.

3.5.1 Maximum Force and Elongation

This was completed to test whether washing at higher temperatures led to changes to the strength of the fabric. Maximum force and elongation was tested after 1, 5 and 10 washes using the procedure described in Section 3.4.1

3.5.2 Tear Test

Determination of tear force of wing shaped test specimens was tested after 1, 5 and 10 washes using the procedure described in Section 3.4.2. This test was chosen to evaluate whether high temperature washing weakened the fabric enough to make it rip or tear more easily.

3.5.3 Dimensional Stability

was tested according to the method described in 3.4.3, after 1, 5 and 10 washes. This test evaluates how the fabric shrinks and/or loses shape after washing.

3.5.4 Wrinkle Recovery

Evaluation was carried out after 1, 5 and 10 washes as detailed in section 3.4.4. Evaluated using ATTC test method 128 wrinkle recovery scale by three observers; the researcher, a member of the production team from the manufacturer and a researcher from Moredun Research Institute (appendix G)

3.5.5 Seam Pucker

Samples were evaluated after 1, 5 and 10 washed as described in section 3.4.5. Three observers as described in section 3.4.4 used AATCC seam pucker evaluation scale (appendix G)

3.5.6 Abrasion Resistance

Three specimens of each fabric sample that had completed 1, 5 and 10 washes along with unwashed samples of each fabric, were tested for abrasion resistance to BS EN ISO 12947-2:1998 76]. They were tested using a 12 Kilopascal weight for the harshest test on a Martindale abrasion and pilling test machine. This test was undertaken to assess whether higher temperature washing affected the abrasion resistance of the fabrics. This was an important consideration as the animals that would be wearing the garment rub up against each other, metal pens, walls, the floor and ground. The fabric chosen for the garment would have to show significant abrasion resistance.

3.6 Animal Wear Trials.

As well as fabric testing, two sample garments were made up and worn by calves for 24 hours before being returned for one wash and evaluation of the fabrics in use and the fastenings after being worn and washed. A new flat-profile velcro fastening was being tested, and actual use rather than lab testing, allowed feedback from animal care staff to be considered along with the performance of the garments. Two garments were tested in this way. One made with texturised nylon and mesh spacer lining and the other made with polypropylene and mesh spacer lining.

CHAPTER 4 – TEST RESULTS AND DISCUSSION

4.1 Materials

This chapter gives the results of testing carried out on the fabrics chosen for the bovine product being developed. The test results were able to indicate the best combination of fabrics to choose for the product and testing also gave a definitive answer to the question of whether a commercially available calf jacket could be modified for use to save design and development time.

4.2 Commercial Calf Jacket Test Results

A commercial calf jacket underwent 10 washes with the intention to then take samples of the outer fabric and lining fabric for testing to compare to the other test samples. The result of the wash test however was so poor that it was clear that any thought of modifying the jackets to save design and development time would not be possible. The following observations were recorded from the wash test:

After the first wash the webbing tape used in the binding and for the fastening straps across the garment had shrunk considerably, as shown in Figure 4.1.

Figure 4.1 Unwashed calf jacket on right and shrunk strapping shown on left pulling garment out of shape.

This resulted in the shrunken strapping pulling the garment out of shape. It was not possible to pull the binding or strapping back to its original shape and by the end of ten washes it was clear that the fabrics chosen for the garment were not compatible. The jacket was taken apart to evaluate further the changes that had taken place during washing. When the wrong side of the fabric was exposed this showed the extent of irreversible puckering due to the strapping being incompatible with the outer fabric. This is shown in Figure 4.2.

Figure 4.2 stitching of webbing to outer fabric. Right side before washing, left, and on wrong side after washing, right.

It had already been observed that the commercial jacket contained an insulating layer that would not be required for the product being developed. After 10 washes this internal layer showed significant deterioration and is shown in Figure 4.3 alongside unwashed wadding to illustrate how much effect the washing had had.

Figure 4.3 Internal wadding, unwashed, left and after ten washes, right.

As the amount of change on the calf jacket after washing was too significant and was not reversible by pulling or pressing it was clear that the commercially available jacket would not be suitable for further modification as it would be unable to withstand the high temperature washing described in Section 3.1. As a result of the poor wash test result only a minimal amount of outer and lining fabric samples were recoverable from the commercial calf jacket. Four outer fabric samples, and four lining fabric samples, 2 warp and 2 weft, were tested for maximum force and elongation as described in Section 3.4.1 and three outer fabric samples and three lining fabric samples were tested for abrasion resistance as described in Section 3.4.6. Full test results for the commercial calf jacket outer and lining fabrics are given in Appendix I.

4.2.1 Maximum force and elongation

The commercial jacket lining failed to give any valid results as the fabric broke at the jaws of the Instron test machine. The maximum force test shows the outer fabric, the rip-stop nylon, was weaker than the other three woven fabrics as can be seen in the mean results shown in Table 4.1. Although the outer fabric shows a better result than the mesh spacer, a direct comparison cannot be made as the mesh spacer fabric is knitted. The commercial jacket outer fabric performed well in the maximum extension test, showing minimal extension.

10 wash maximum force (Newtons)	warp	weft
Commercial jacket	1279.5	846
Polypropylene	2220	2000
Texturised nylon	1940	1300
Mesh spacer	860	722

Table 4.1 Mean results of commercial jacket outer fabric maximum force test compared to the other fabrics being tested

10 wash Maximum Extension (mm)	warp	weft
Commercial jacket	84.5	58.5
Polypropylene	65.9	55
Texturised nylon	117.8	113.6
Mesh spacer	96.6	174.2

Table 4.2 Mean results of commercial jacket outer fabric maximum extension test compared to the other fabrics being tested

4.2.2 Abrasion resistance

The commercial jacket outer fabric performed better than the polypropylene but less well than the texturised nylon and mesh spacer fabrics. The commercial jacket lining broke down at a very early stage. The results appear to indicate that the commercial jacket fabrics may not be as robust and durable as the texturised nylon and mesh spacer fabrics. Combined with the poor wash test results, it was evident that other fabrics would have to be chosen to achieve a compatible combination to develop into the bovine product.

10 wash Abrasion resistance (Martindale method)	Test cycles to breakdown
Commercial jacket (outer)	73000
Commercial jacket (lining)	10000
Polypropylene	11666.7
Texturised nylon	1000000
Mesh spacer	81333.3

Table 4.3 Mean results of commercial jacket fabrics abrasion resistance test compared to the other fabrics being tested

4.3 Textile Choice

The three textiles being tested; the polypropylene, the texturised nylon and the mesh spacer fabric detailed in section 3.5 were tested in both unwashed and washed state as described in Section 3.

4.4 Test Results: Unwashed Fabrics

Unwashed samples of fabrics were tested to use as a benchmark against which test results could be compared after high temperature washing.

4.4.1 Maximum Force and Elongation

Maximum force testing of the unwashed fabrics, shown in Appendix D and summarised in Figures 4.4 and 4.5,   indicated that each fabric had low variability in strength in both warp and weft directions. The polypropylene performed better in terms of strength on this test. The mesh spacer was the least strong of the three fabrics, but is should be noted that this is a knit fabric and the other two are woven so it was inclined to stretch prior to bursting. The only direct comparison that can be made was between the two woven fabrics: the texturised nylon and the polypropylene, and both performed well showing broadly similar and acceptable results. As expected the warp direction was stronger than the weft direction in both woven fabrics. However, the fabric was strong enough for the application in both directions.

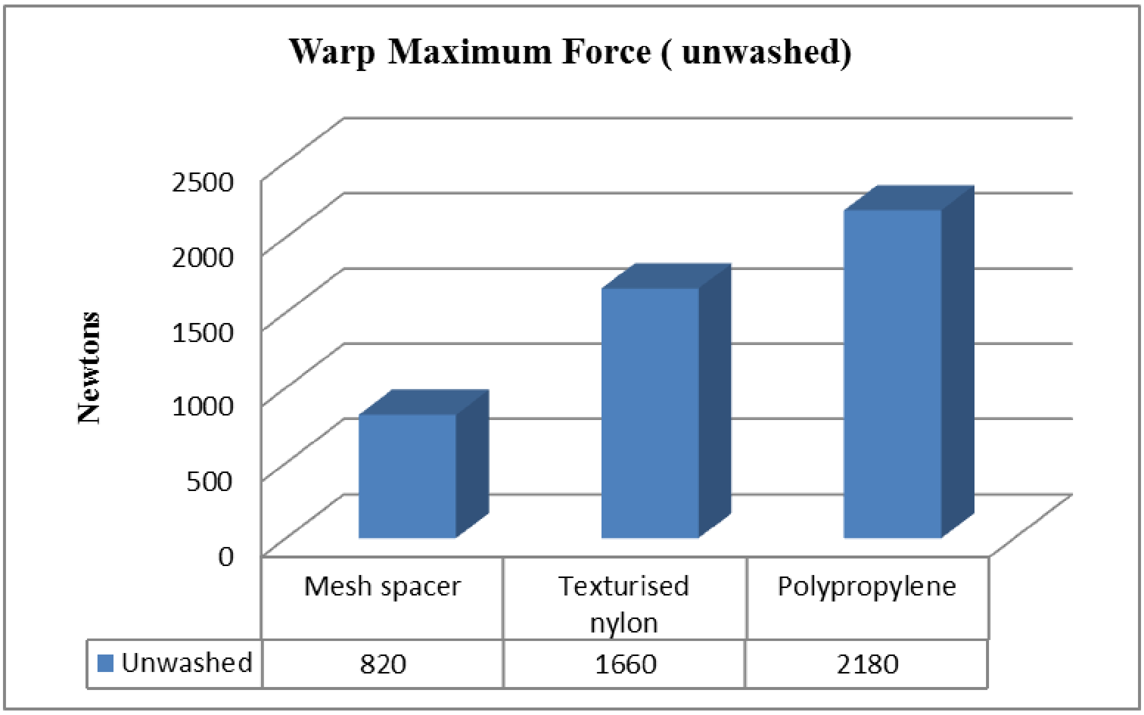


Figure 4.4 Warp maximum force of unwashed fabrics, mean results

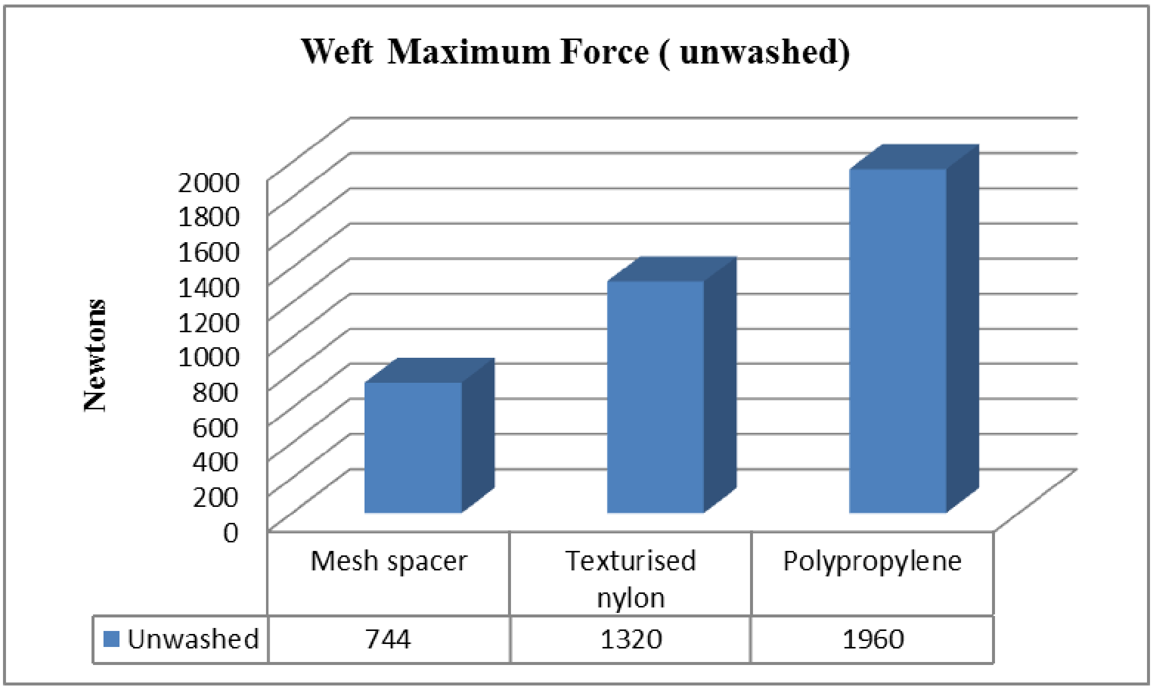


Figure 4.5 Weft maximum force of unwashed fabrics, mean results.

Maximum extension (elongation) indicated how much the fabric stretched, or extended before bursting. Figures 4.6 and 4.7 show the test results for maximum extension in the warp and weft directions. The mesh spacer fabric, being knitted performed very well as stretch is an inherent quality of a knitted structure. The product being developed did not require any extensibility, but the results confirm that all fabrics being tested were compatible as there was no significant difference between the three fabrics.

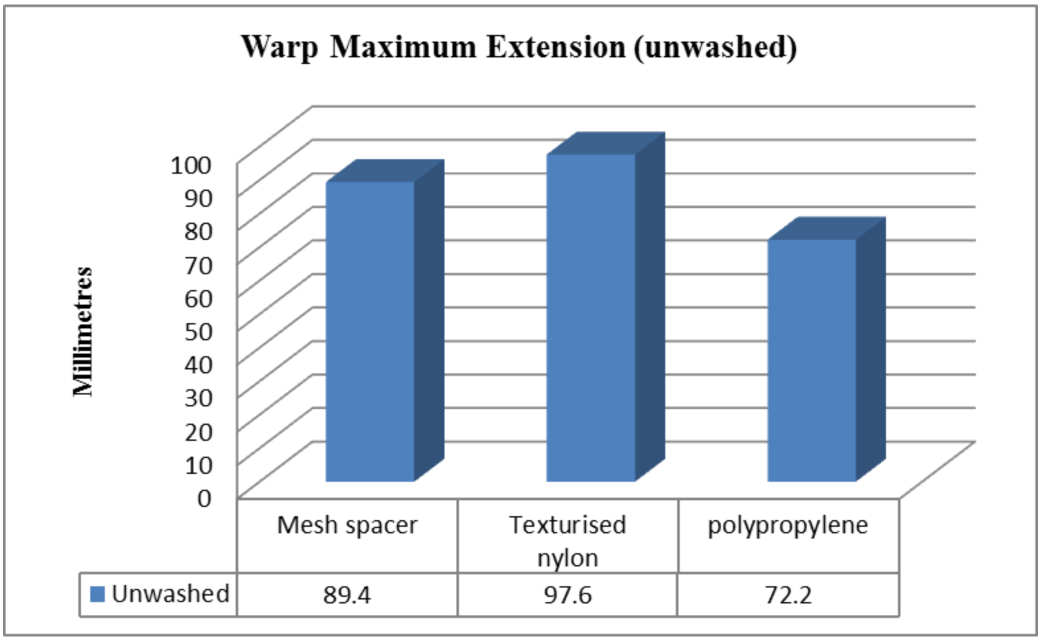


Figure 4.6 Warp maximum extension (unwashed)

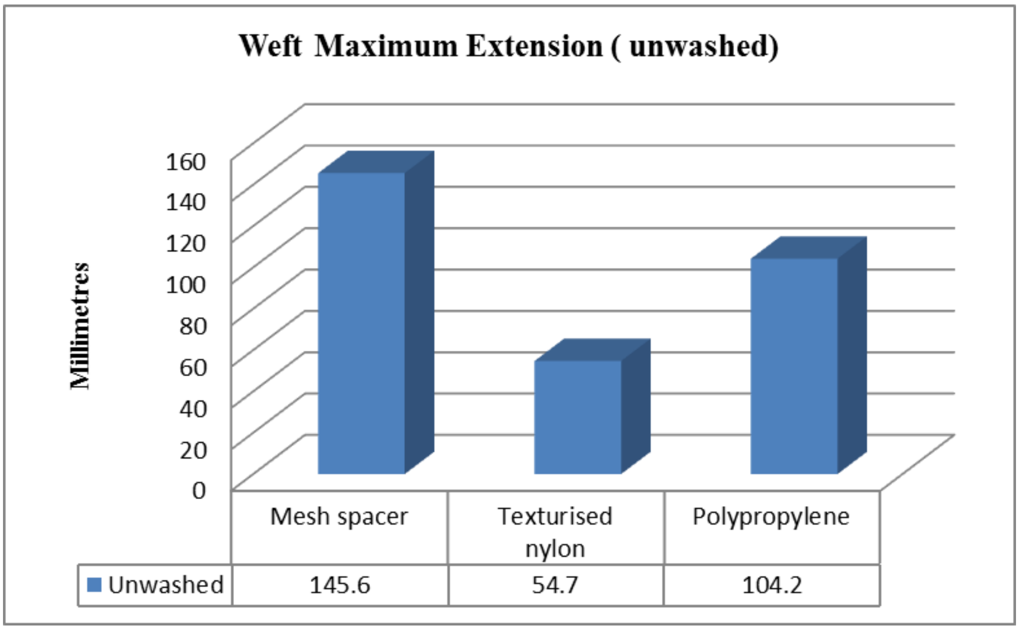


Figure 4.7 weft maximum extension (unwashed)

4.4.2 Tear Test

Tear testing was relevant to the product being developed as it would be worn by livestock and may be snagged on wood or metal pens, brick walls, floors and the ground as well as other animals. It was important to have an understanding of how easily torn each fabric was. Tear testing is used for woven fabrics, however it was decided to also test the mesh spacer fabric. Unfortunately every mesh knitted sample failed to tear along the required distance. Figure 4.8 shows the completed samples and although each has a consistent tear profile no valid test results were gained.

Figure 4.8 Mesh spacer tear test samples.

The two woven fabrics did provide valid test results and as shown in figures 4.9 and 4.10 that the polypropylene fabric was over four times stronger than the texturised nylon across both the warp and weft threads.

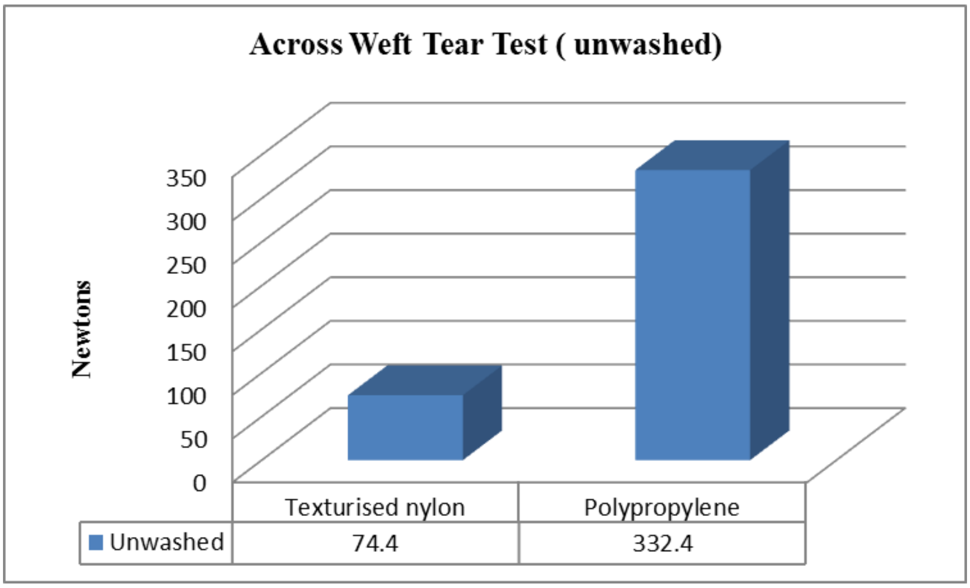


Figure 4.9 Across weft tear test

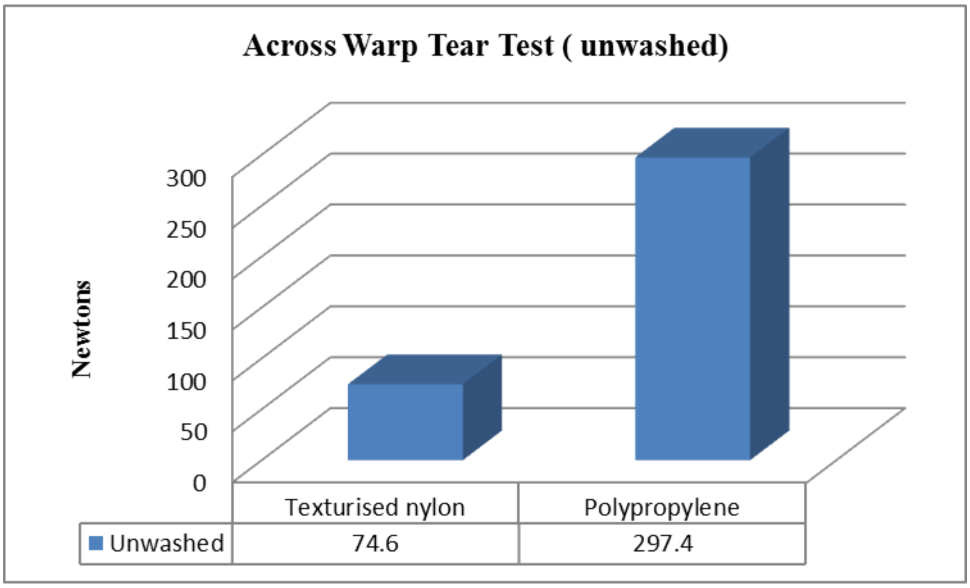


Figure 4.10 across warp tear test

4.4.3 Dimensional Stability

The two outer fabrics had each been stitched and bound to the lining fabric so it was important to check the measurements prior to washing to ensure that the stitching process through both layers of fabric and on the bound edge had not caused any dimensional change. Figure 4.11 shows one of the texturised nylon and mesh spacer lined samples stitched in the warp and weft direction and also bound in the warp and weft direction, and lying flat with no measureable dimensional change post sewing and prior to washing.

Figure 4.11 Unwashed texturised nylon and mesh spacer. stitched and bound

4.4.4 Wrinkle Recovery

This test was carried out on the washed samples as wrinkling takes place during the washing process. It is worth noting though that as in section 4.4.3 above and shown in Figure 4.11, the stitched and bound samples were checked to ensure that prior to washing that the sewing process had not caused any wrinkling.

4.4.5 Seam Pucker

Reflecting the comments made in sections 4.4.3 and 4.4.4 and shown in Figure 4.12 the stitched and bound samples were checked for evidence of seam pucker after sewing and prior to washing. Close inspection of Figure 4.11 appears to show some light puckering and fullness on the bottom right and bottom left of the sample, this is the result of the sample being stuck vertically on an angled board for examination and is the result of the two fabrics having no stitching to secure them together. The stitched and bound fabrics were flat when laid on a horizontal surface. As part of the product development process resulted in the decision to use Molle strips as described in Section 5.3.2 and shown in Figure 5.7. A polypropylene webbing strip was stitched to two fabric test samples, one consisting of polypropylene with a mesh spacer backing and one consisting of texturised nylon with a mesh spacer backing and shown in Figure 4.12. This test was undertaken after the commercial calf jacket performed poorly after washing due to the strapping used across the garment and for the bound edge the outcome of which is discussed in Section 4.2.

Figure 4.12 Polypropylene webbing strip stitched to fabric sample

4.4.6 Abrasion Resistance

Abrasion resistance testing of all three fabrics gave the first indication that the texturised nylon fabric far exceeded the abrasion resistant qualities of the other two fabrics. It also indicated prior to washing, see Figure 4.13, that although the polypropylene fabric had performed well in all other tests it had an unexpectedly and unacceptably poor result. Further discussion on abrasion resistance testing is offered in Section 4.5.6 which considers the results of washed and unwashed samples.

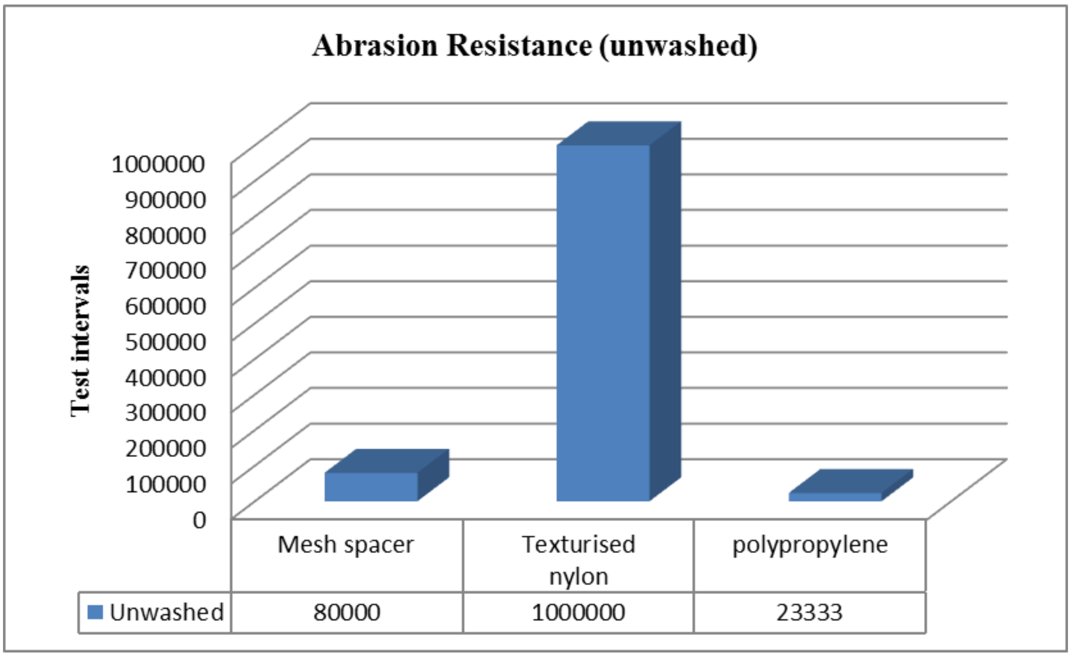


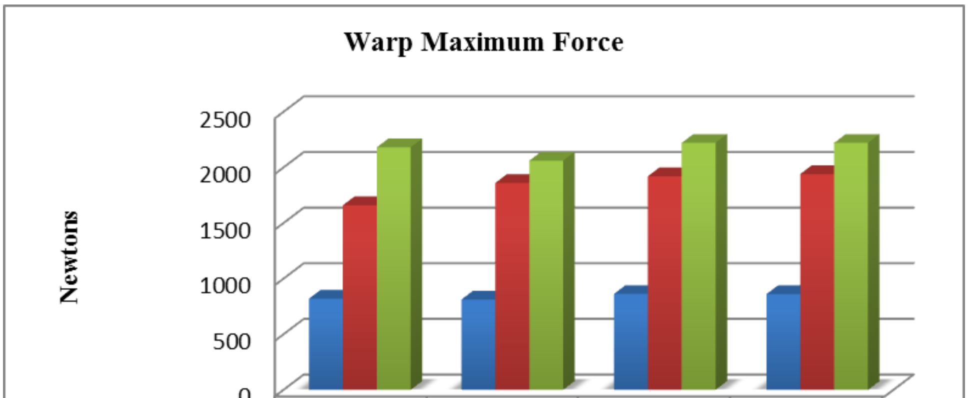
Figure 4.13 Abrasion resistance of unwashed fabrics

4.5 Post Wash Testing

To show the extent of any change, the post wash test results include the unwashed results as for most tests carried out, the greatest change took place after the first wash. In order to give a balanced report on the test findings all post-wash results were compared to the unwashed results.

4.5.1Maximum force and elongation

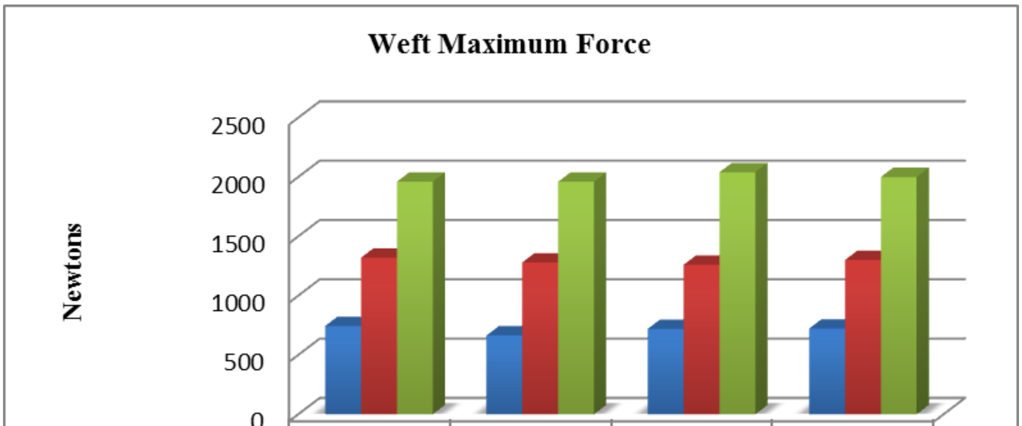
In the samples cut in the warp direction, the results of the maximum force tests are shown in Appendix D and summarised in Figure 4.14. The mesh spacer fabric burst with less force after one wash but regained strength after 5 and 10 washes. The polypropylene fabric also showed this. The texturised nylon also showed the greatest change after the first wash but became 12% stronger whereas the other two fabrics initially weakened. This could have been due to the polyethylene coating on the texturised nylon or perhaps simply compaction of the fibres as the fabric was more tightly woven with finer yarn than the polypropylene.



	Unwashed	1 wash	5 wash	10 wash
Mesh spacer	820	812	862	860
Texturised nylon	1660	1860.2	1920	1940
Polypropylene	2180	2060	2220	2220

Figure 4.14 Warp maximum force for all fabrics

For the samples cut in the weft direction, the results of the maximum force tests are shown in Figure 4.15. These differed from the warp samples in that the mesh spacer fabric again showed the greatest amount of change after one wash, again becoming slightly weaker and then able to withstand increasing force again, but not surpassing the unwashed result as in the warp test. The texturised nylon weakened after the first and fifth washes but regained strength almost back to unwashed level after 10 washes. This may be due to quality issues with the weaving process or the coating on the back of the fabric. The polypropylene performed well, it showed a static result after one wash but gained in strength after five and ten washes.



	Unwashed	1 wash	5 wash	10 wash
Mesh spacer	744	664	720	722
Texturised nylon	1320	1280	1260	1300
Polypropylene	1960	1960	2040	2000

Figure 4.15 Weft Maximum Force for all fabrics

The warp maximum extension test results in Figure 4.16 showed that although all three fabrics showed some changes between washes there was no general significant change in any. The mesh spacer and texturised nylon fabric showed increased extension after washing, this is likely to be due to the mesh spacer being a knitted fabric which would be expected to show greater extension and the texturised nylon having a polyethylene coating which may have contributed to greater extensibility. It could also be due to some shrinkage initially that relaxed again with subsequent washes. The polypropylene showed reduced extension, this fabric is neither knitted nor coated yet despite reduced extension it still showed increasing tensile strength in maximum force tests.

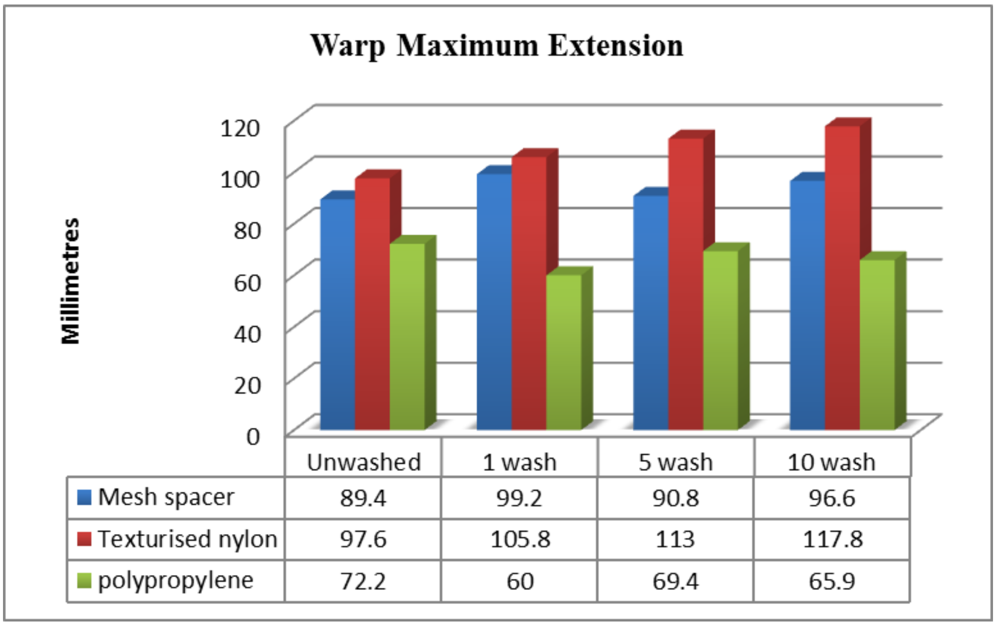


Figure 4.16 Warp maximum extension test for all fabrics

The three fabrics showed greater extensibility in the weft test samples, see Figure 4.17, compared to the warp test samples. Again there were no substantial differences across washes, the two woven fabrics showed a consistent change and the knitted fabric showed increasing extension which would be within an acceptable range for a knit structure.

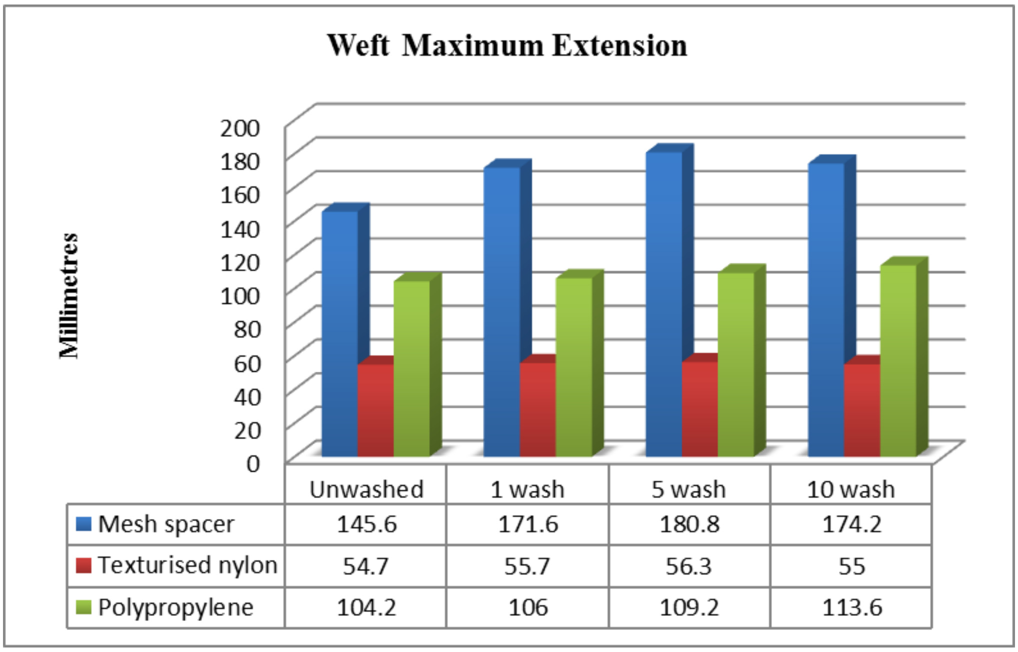


Figure 4.17 Weft maximum extension test for all fabrics

4.5.2 Tear Test

As indicated in Section 4.4.2 and shown in Figure 4.8 the mesh spacer fabric failed to produce any valid tear test results. Figure 4.18 shows the result of tear tests across the weft yarns for the texturised nylon and the polypropylene fabrics. The polypropylene's tear strength was dramatically reduced after the first wash, and slightly reduced after the fifth wash but regained some tear strength after ten washes. The texturised nylon became slightly weaker after the first wash but gained strength over subsequent washes.

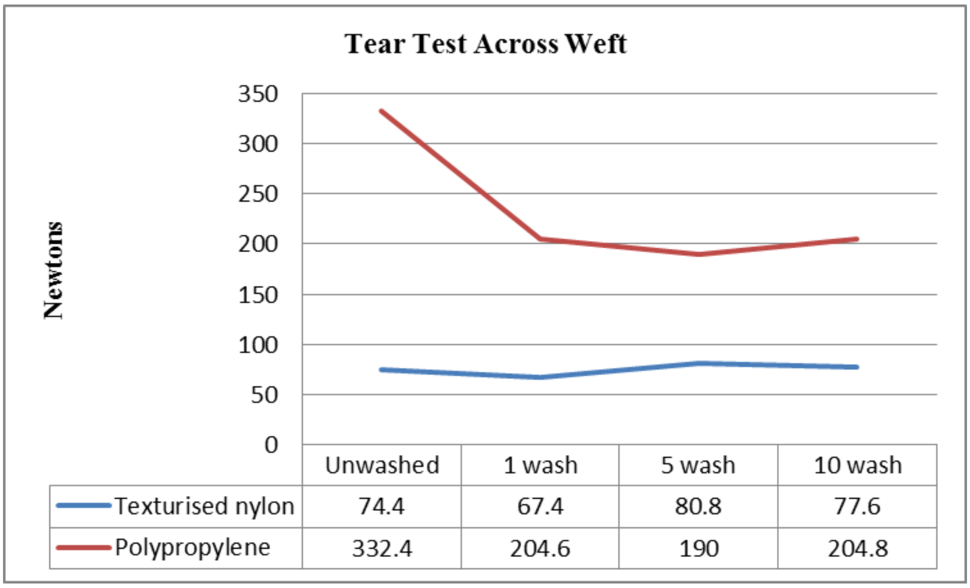


Figure 4.18 Tear test across weft yarns

Across the warp yarns, the results shown in Figure 4.19, testing showed that the polypropylene's resistance to tearing diminished with each subsequent set of washes (and dramatically after the first wash), whereas the texturised nylon fabric again lost some tenacity after the first wash but increased its tear resistance over subsequent washes.

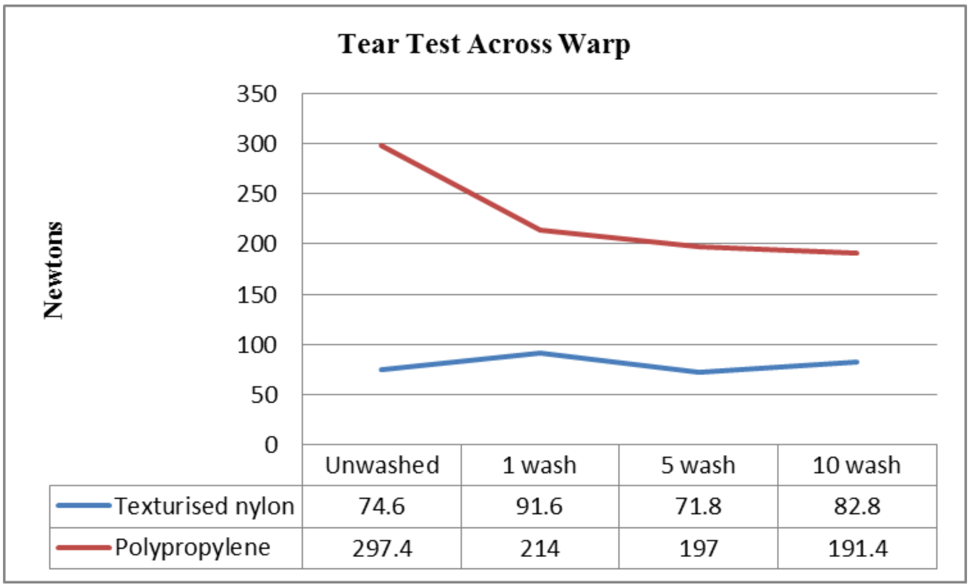
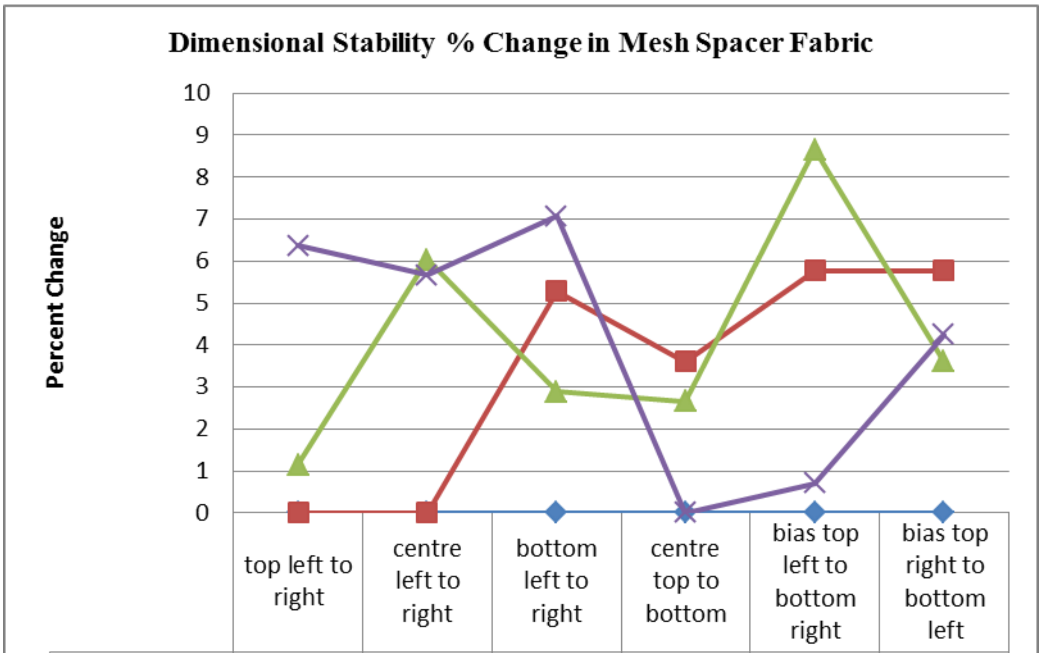


Figure 4.19 Tear test across warp yarns.

4.5.3 Dimensional Stability

Dimensional stability measures the percent change between markers on each fabric sample. The charts in this section show the mean percent change for each fabric tested.

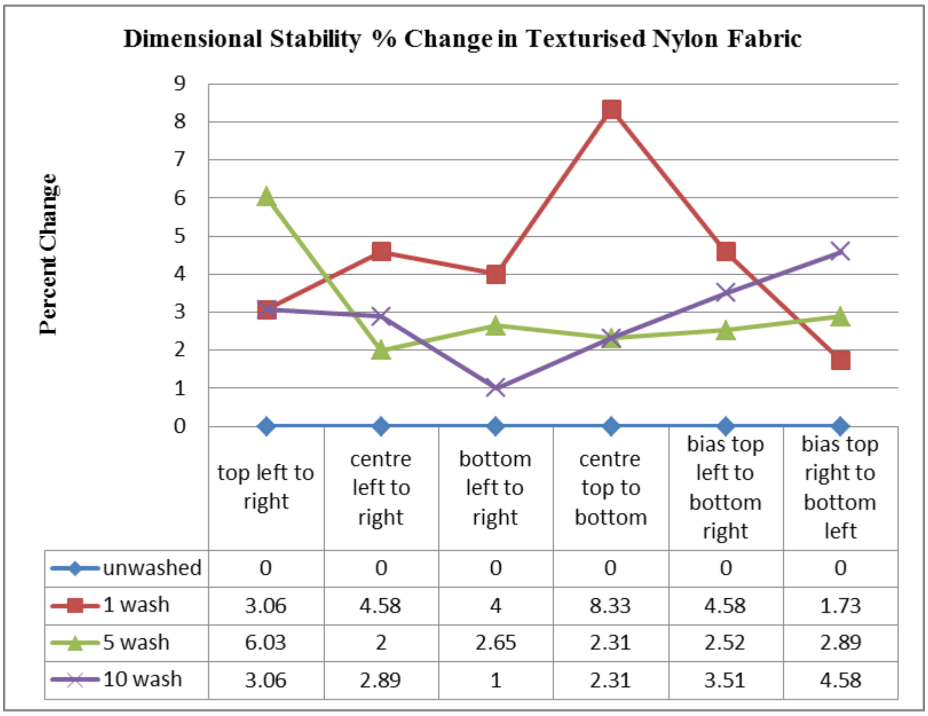
The results for the mesh spacer fabric is shown in Figure 4.20. It must be remembered again that this is a knitted fabric, knitted over two beds with spacer yarns in between the front and back layers to give a raised 3D appearance, and has more stretch due to its knitted structure than would be expected to find in a woven fabric. Although the maximum elongation test results shown in Figures 4.16 and 4.17 show increasing extensibility, the dimensional change measured was less than 9% showing that this fabric retains its shape well across washes despite being a knit fabric that might be expected to loosen with washing.



	top left to right	centre left to right	bottom left to right	centre top to bottom	bias top left to bottom right	bias top right to bottom left
unwashed	0	0	0	0	0	0
1 wash	0	0	5.29	3.61	5.77	5.77
5 wash	1.15	6.03	2.89	2.65	8.66	3.61
10 wash	6.36	5.66	7.07	0	0.71	4.24

Figure 4.20 Dimensional stability mean % change in width, length and bias in mesh spacer fabric

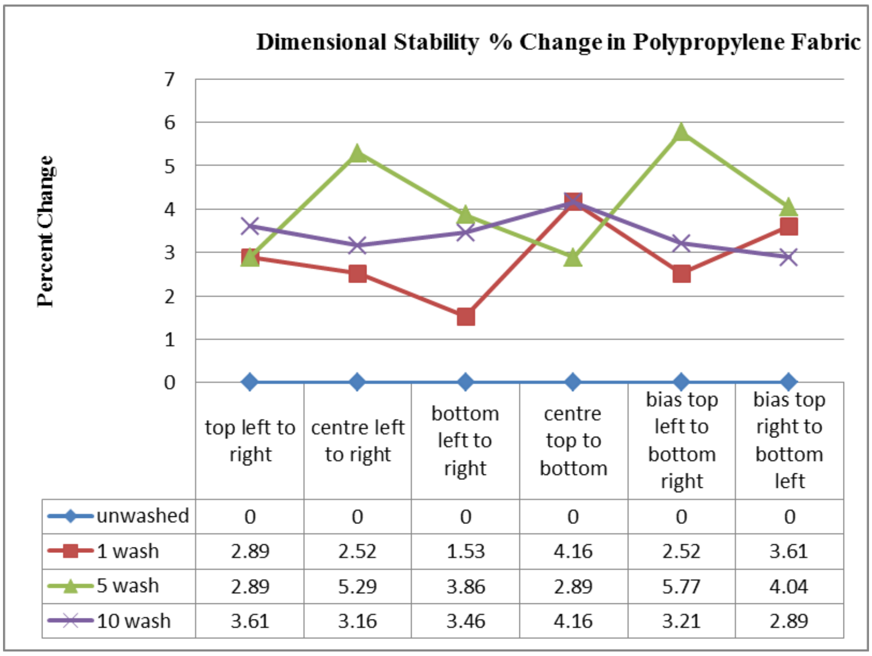
The texturised nylon fabric also showed less than 10% change across washes, if the 6.03% and 8.33% results shown in Figure 4.21 are anomalous and due to quality issues in weaving and acknowledged by the manufacturer, then the fabric shows less than a 5% dimensional change indicating that this fabric shows it is robust enough to withstand repeated high temperature washes. Even if the possibly anomalous results are a true representation of the fabric's performance, it closely reflects the result of the mesh spacer fabric which would indicate that these two fabrics are compatible with each other.



	top left to right	centre left to right	bottom left to right	centre top to bottom	bias top left to bottom right	bias top right to bottom left
unwashed	0	0	0	0	0	0
1 wash	3.06	4.58	4	8.33	4.58	1.73
5 wash	6.03	2	2.65	2.31	2.52	2.89
10 wash	3.06	2.89	1	2.31	3.51	4.58

Figure 4.21 Dimensional stability mean % change in width, length and bias in texturised nylon fabric

The polypropylene fabric dimensional stability test results shown in Figure 4.22, also performed well with less than 6% change measured compared to the unwashed sample, having the greatest variance after five washes. At this stage, this fabric also looks compatible with the mesh spacer fabric.



	top left to right	centre left to right	bottom left to right	centre top to bottom	bias top left to bottom right	bias top right to bottom left
unwashed	0	0	0	0	0	0
1 wash	2.89	2.52	1.53	4.16	2.52	3.61
5 wash	2.89	5.29	3.86	2.89	5.77	4.04
10 wash	3.61	3.16	3.46	4.16	3.21	2.89

Figure 4.22 Dimensional stability mean % change in in width, length and bias in polypropylene fabric

4.5.4 Wrinkle Recovery

The unwashed samples had not undergone any washing so remained smooth and scored the maximum wrinkle–free score of 5. The two outer fabrics, the texturised nylon and the polypropylene were both stitched and bound to the mesh spacer lining fabric and were evaluated after 1 wash, 5 washes and 10 washes. The individual scores given are in Appendix G. The results for the polypropylene and mesh spacer lining are given in Figure 4.23. This shows that the greatest amount of change took place after the first wash, but this amount of change was not cumulative and after 5 and 10 washes no significant further wrinkling was observed

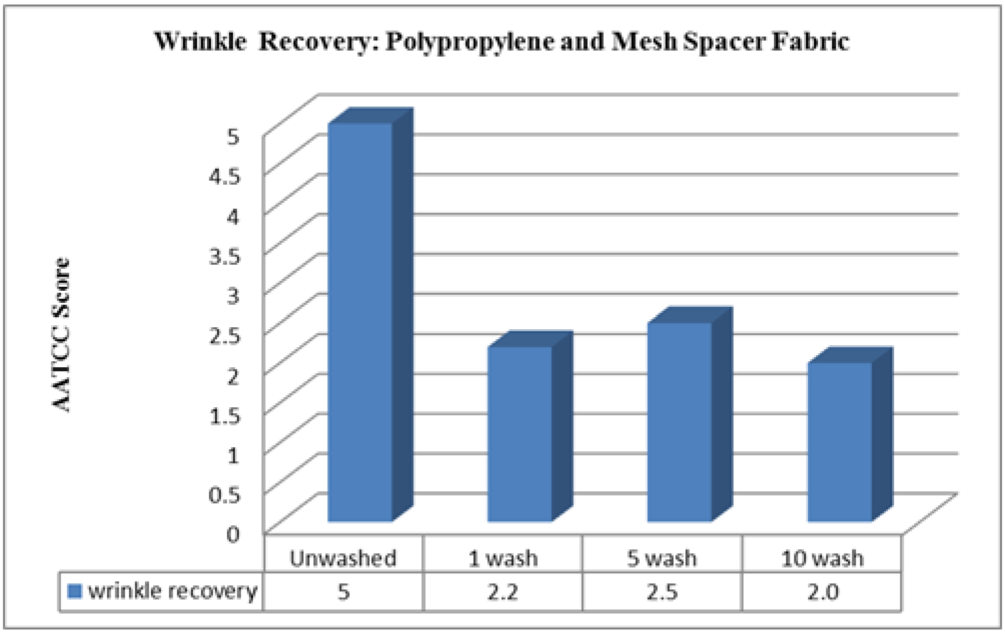


Figure 4.23 Mean evaluation results for wrinkle recovery: polypropylene and mesh spacer fabric.

Figure 4.24 shows from left to right the polypropylene and mesh spacer fabric after 1, 5 and 10 washes. Wrinkling can be seen becoming progressively more pronounced.

Figure 4.24 From left to right, 1 wash, 5 washes and 10 washes

The texturised nylon and mesh spacer sample results are shown in Figure 4.25 These showed less change than the polypropylene after the first wash and very minimal further change after the fifth and tenth washes.

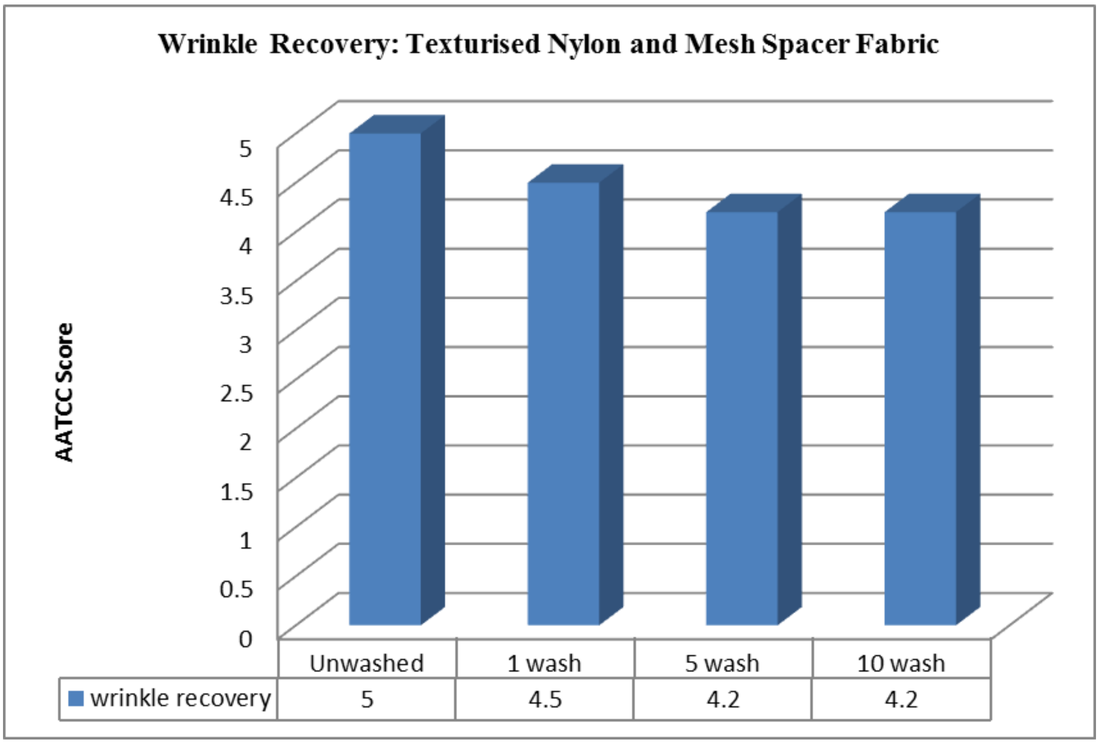


Figure 4.25 Mean evaluation results for wrinkle recovery: texturised nylon and mesh spacer fabric.

Figure 4.26 shows from left to right the texturised nylon and mesh spacer fabric after 1, 5 and 10 washes.

Figure 4.26 From left to right, 1 wash, 5 washes and 10 washes.

4.5.5 Seam Pucker

The seam pucker test results showed that both outer fabrics were compatible with the mesh spacer lining fabric. The stitching showed only a little change on both the polypropylene shown in Figure 4.27, and Texturised nylon, shown in Figure 4.28.

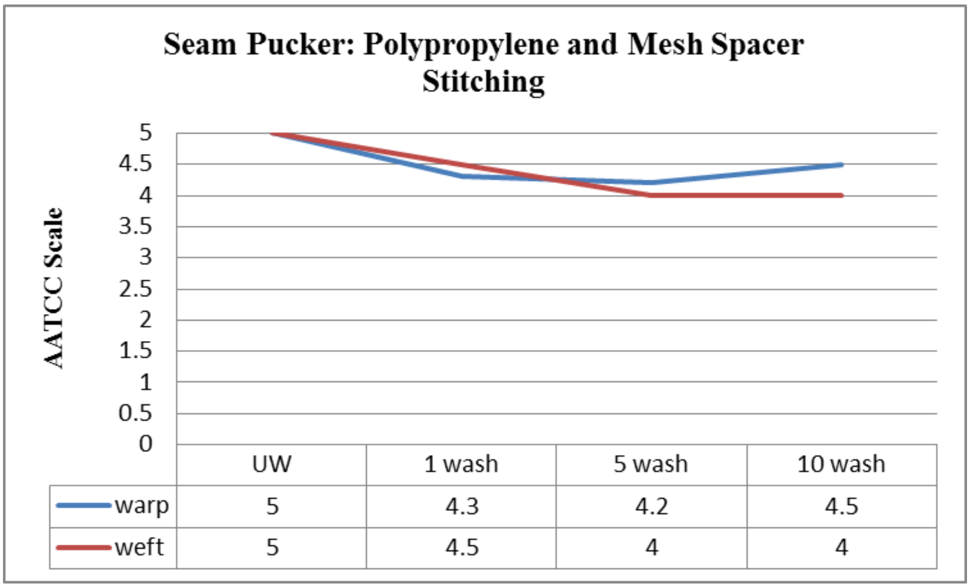


Table 4.27 Seam pucker: polypropylene and mesh spacer stitching mean evaluation

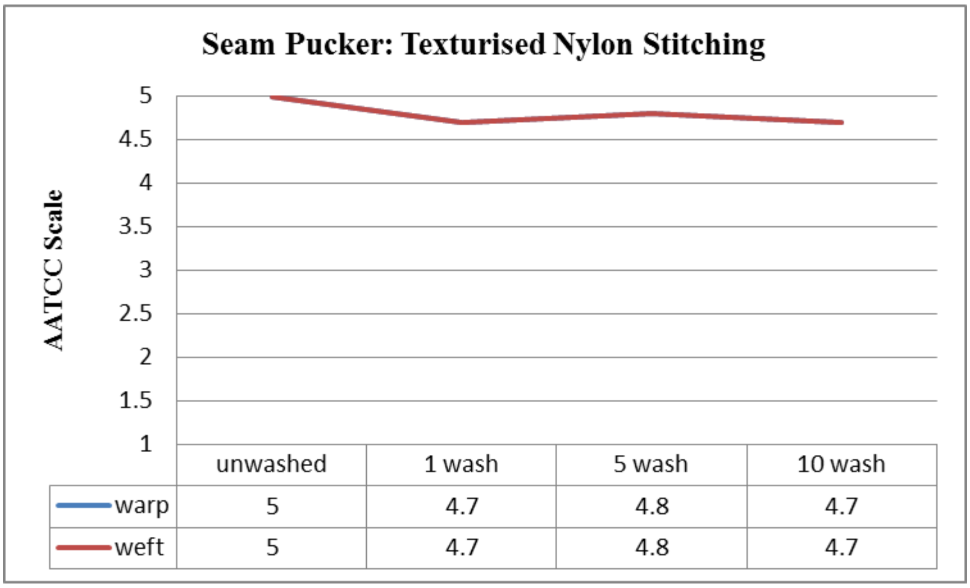


Table 4.28 Seam pucker: Texturised nylon stitching mean evaluation

The bound edge of both sets of samples performed similarly, see Figures 4.29 and 4.30 with minimal change in appearance. It is also notable that the results showed no great difference between the warp and weft direction.

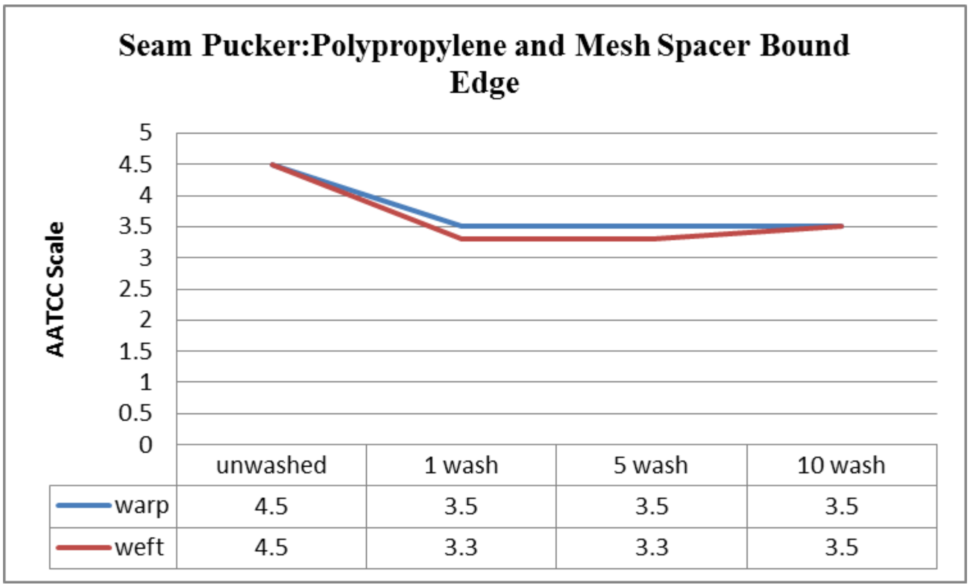


Figure 4.29 Polypropylene and mesh spacer bound edge, mean evaluation

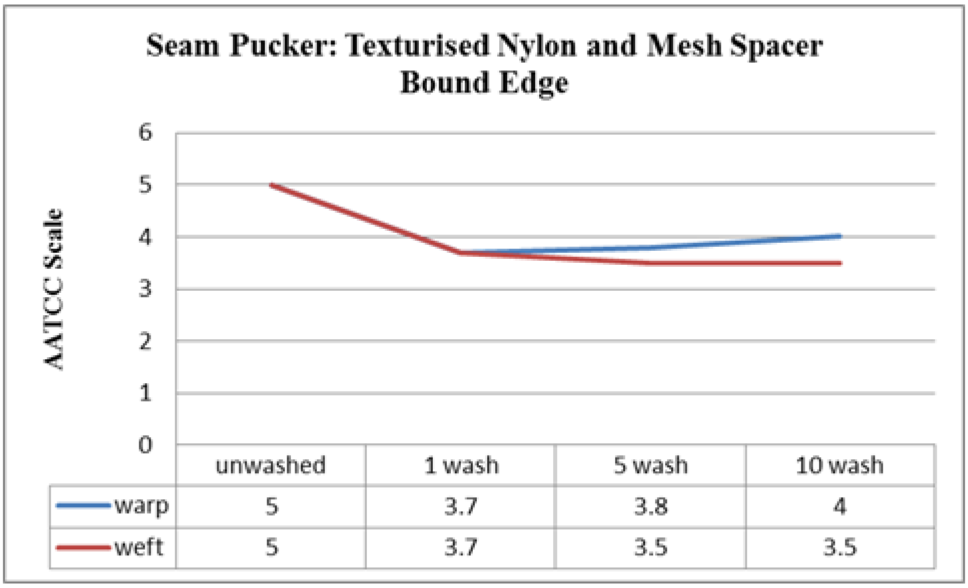


Figure 4.30 Seam pucker: Texturised nylon and mesh spacer bound edge, mean evaluation

The samples that had the webbing strap stitched on to indicate if the molle strips would distort the fabrics did show some changes, see Figures 4.31 and 4.32. These results would be discussed with the manufacturer as a lighter weight of webbing strip and different type of stitching thread could improve the outcome.

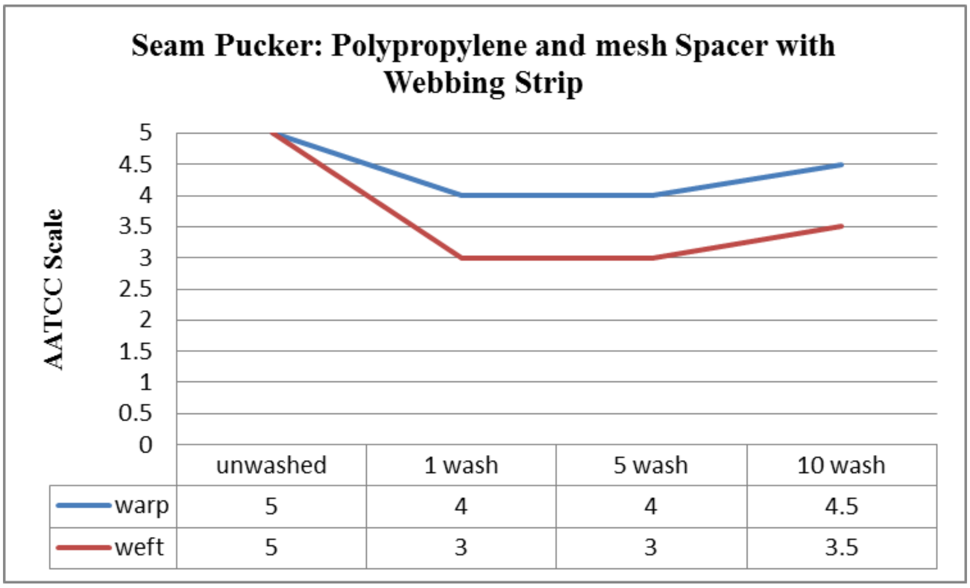


Figure 4.31. Seam pucker: polypropylene and mesh spacer with webbing strip mean evaluation

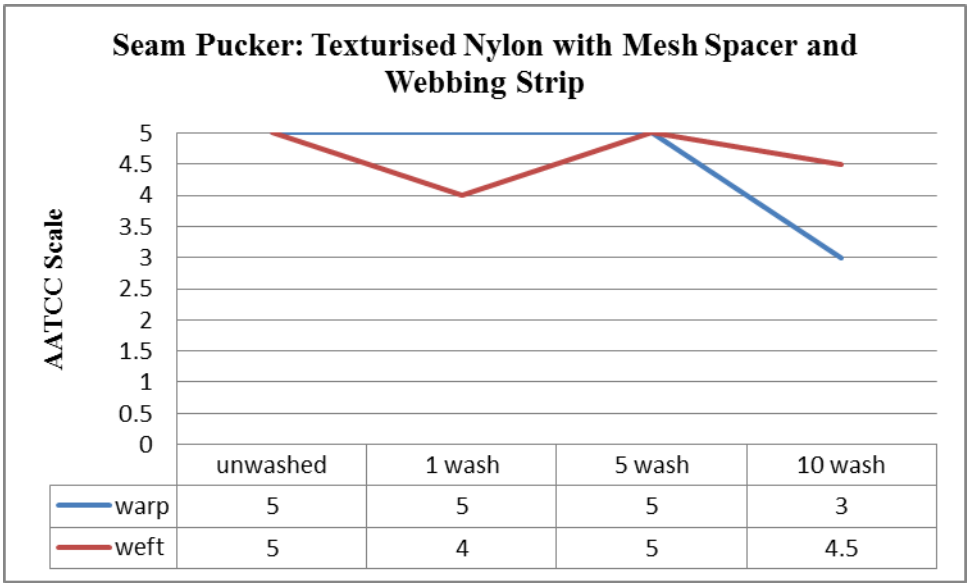


Figure 4.32. Seam pucker: texturised nylon with mesh spacer and webbing strip mean evaluation.

4.5.6Abrasion Resistance

Mesh spacer fabric observations.

Testing had already indicated that this fabric had significant strength. Testing for abrasion resistance, shown in Figure 4.33 and Appendix H, continued to confirm that this fabric would be well suited for use in the bovine product.

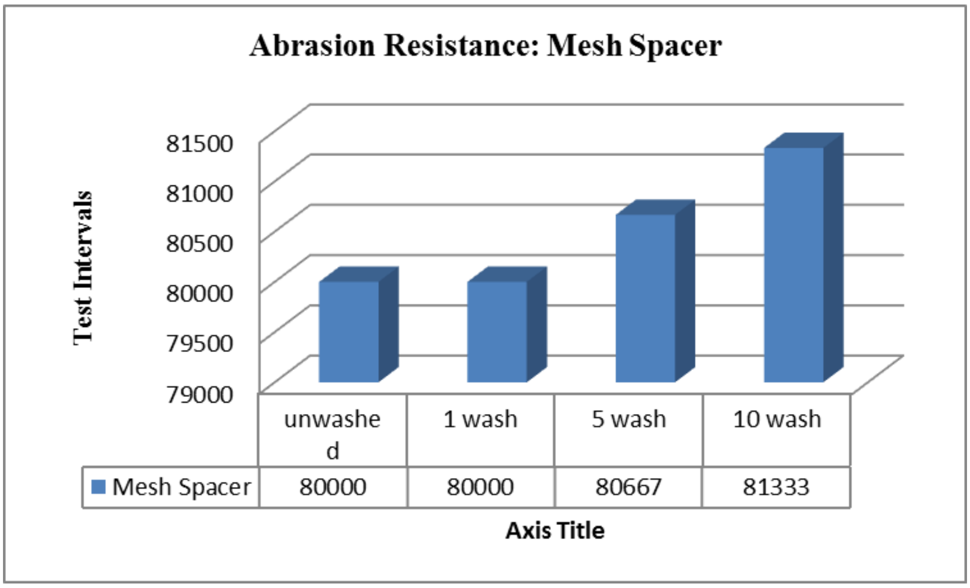


Figure 4.33 Abrasion Resistance : Mesh Spacer, mean results.

A hard-wearing upholstery textile would be required to withstand 40,000 test cycles in a Martindale abrasion testing machine. The fact that the fabric was still wholly intact at 70,000 was surprising. At 15,000 test cycles, raised fibres were noted to be visible on the fabric surface and from 20,000, test cycles, shown in Figure 4.34, onward the surface appeared fuzzy. However despite these two observations and also that the abradant on the machine had obvious black fibres from the fabric, on inspection the fabric was still structurally sound with breaking of one thread not occurring until 80,000 – 82,000 test cycles had been completed.

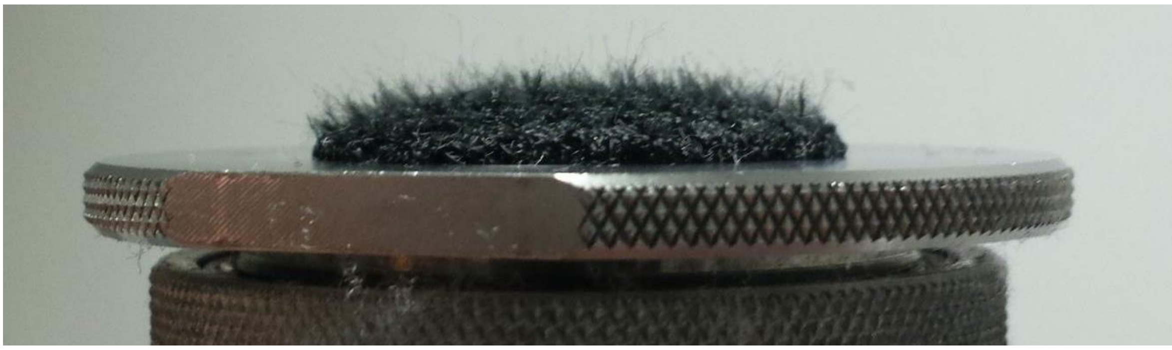


Figure 4.34 Fuzzy surface after 20,000 test cycles

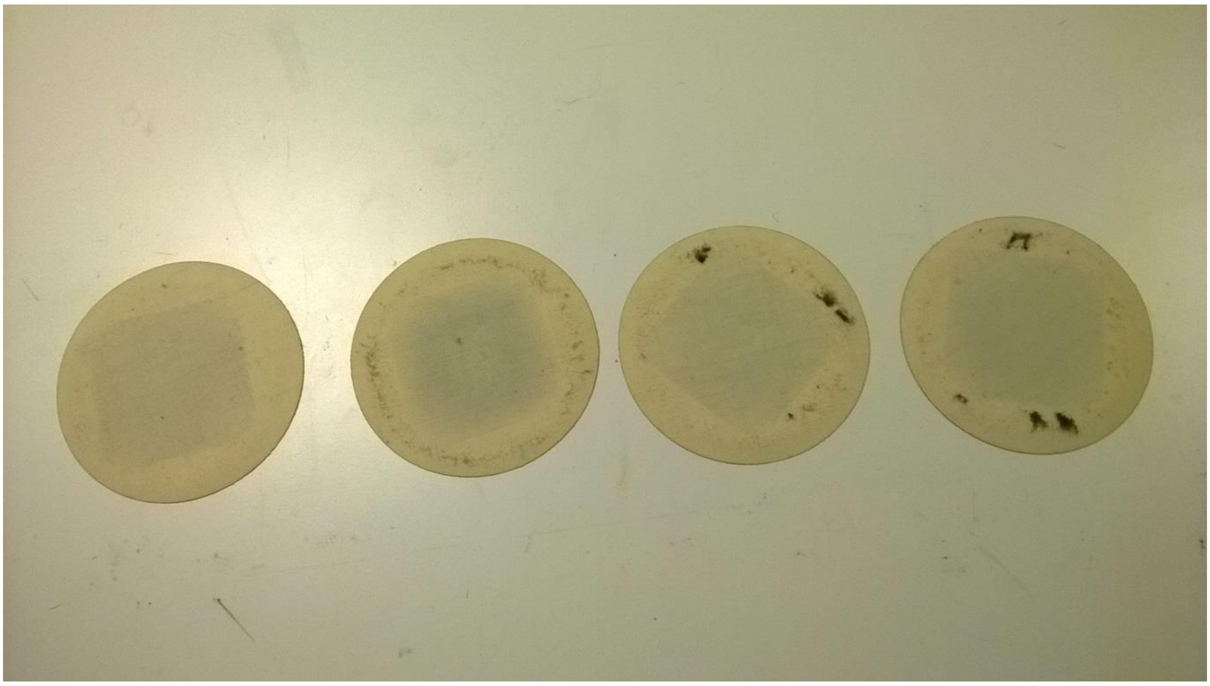


Figure 4.35 Abradant change at 50,000 test cycles.

Figure 4.35 shows the abradant fabric after 50,000 test cycles. fibres from the fabric being tested are visible. The discs from left to right show the fabric unwashed, 1 wash, 5 wash and 10 wash. After 70,000 test cycles, the structure is still clearly visible, see

Figure 4.36. The mesh spacer fabric finally broke down after 80,000 – 82,000 test cycles, shown in Figure 4.37.

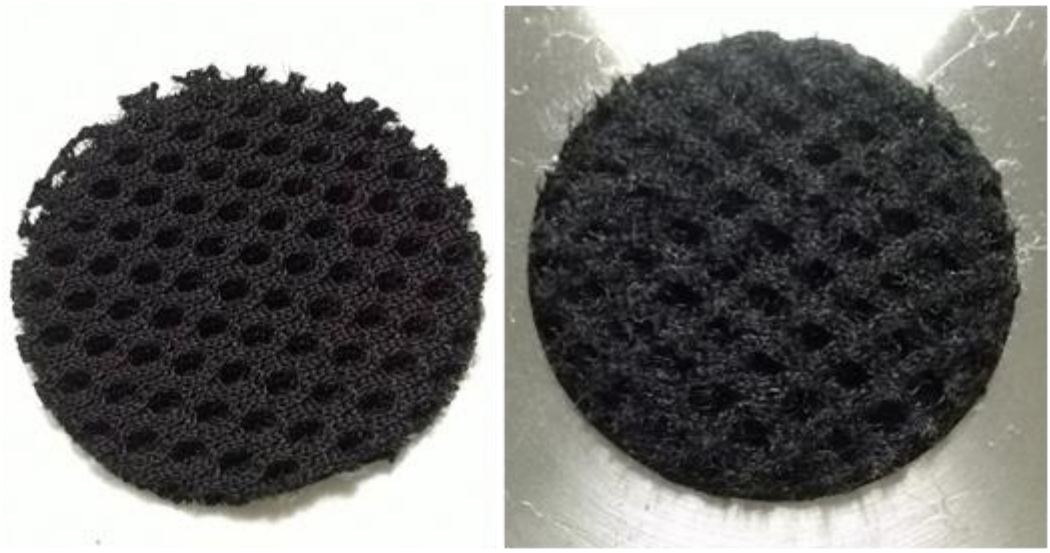


Figure 4.36 the untested fabric, left and after 70,000 test cycles, right

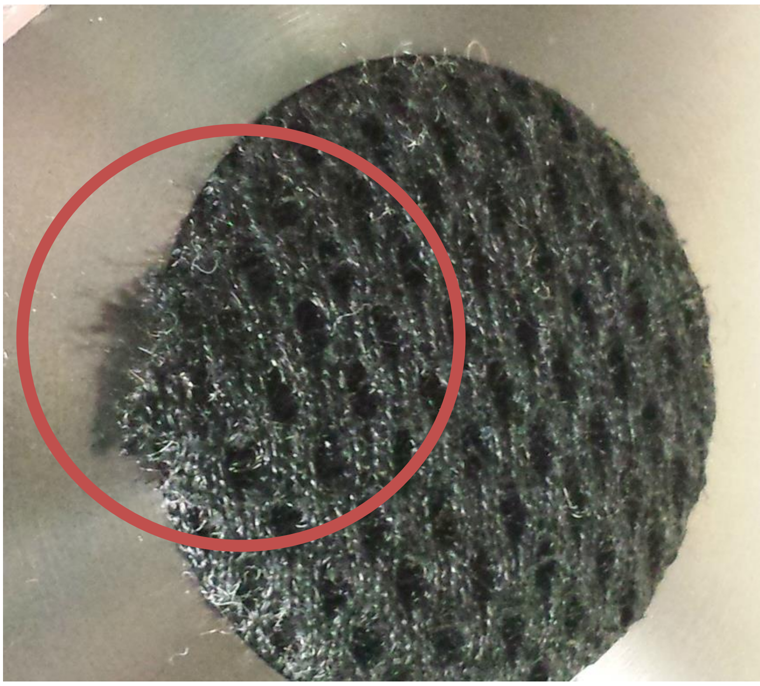


Figure 4.37 Final breakdown achieved at 80,000 to 82,000 test cycles.

Texturised nylon

The abrasion test results shown in Figure 4.38 are as a result of stopping the testing after the fabric withstood one million test cycles without breaking down. This result extends far beyond expectation. High temperature washing did not apprear to have affected the abrasion resistance of the fabric at all. Despite some quality issues with the consistency of the weave in some batches of this fabric already discussed, testing has shown this to be extremely hard wearing and well suited to the development of the bovine product.

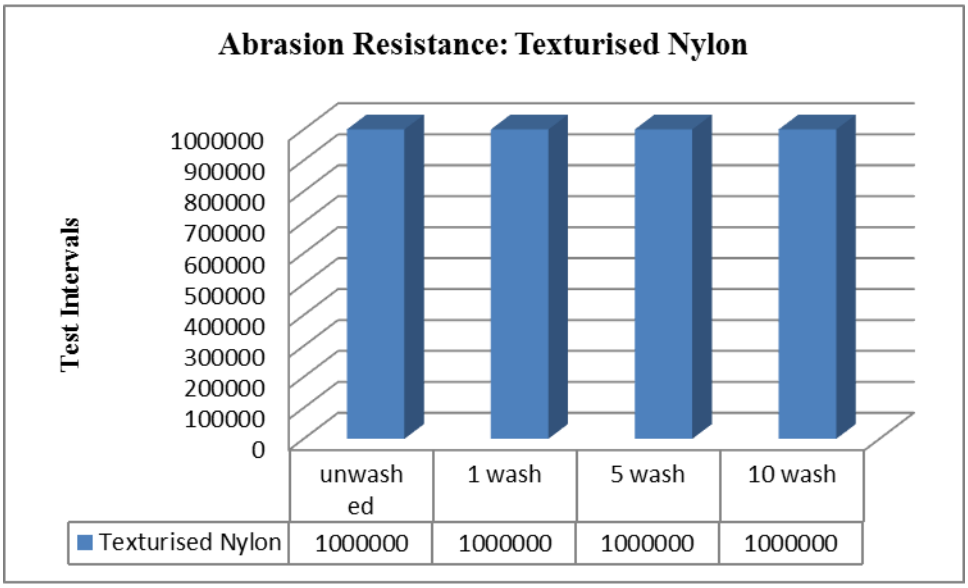


Figure 4.38 Abrasion resistance: Texturised Nylon

After 20,000 Test cycles, shown in figure 4.39, the fabric was noted as showing raised fibres. All test samples from the unwashed to the 10 wash samples became fuzzy at the same time. The test was stopped at 1 million test cycles and Figure 4.40 shows the fabric structure still intact.

Figure 4.39 Unwashed Texturised nylon, fuzzy after 20,000 test intervals

Figure 4.40 after 1 million test cycles the structure is still clearly intact. Normal resolution left, and 5 x magnification right.

Polypropylene Fabric

This fabric had consistently performed well in testing showing strength and durability and also good compatibility with the mesh spacer fabric. The results of abrasion resistance testing shown in Table 4.41 show the fabric breaking down at less than 12,000 test cycles. A photograph of a sample is shown in Figure 4.42 demonstrating the extreme lack of abrasion resistance. This was surprising given that up to this point the test results seemed to indicate that this fabric offered a good level of functionality and suitability for the bovine product.

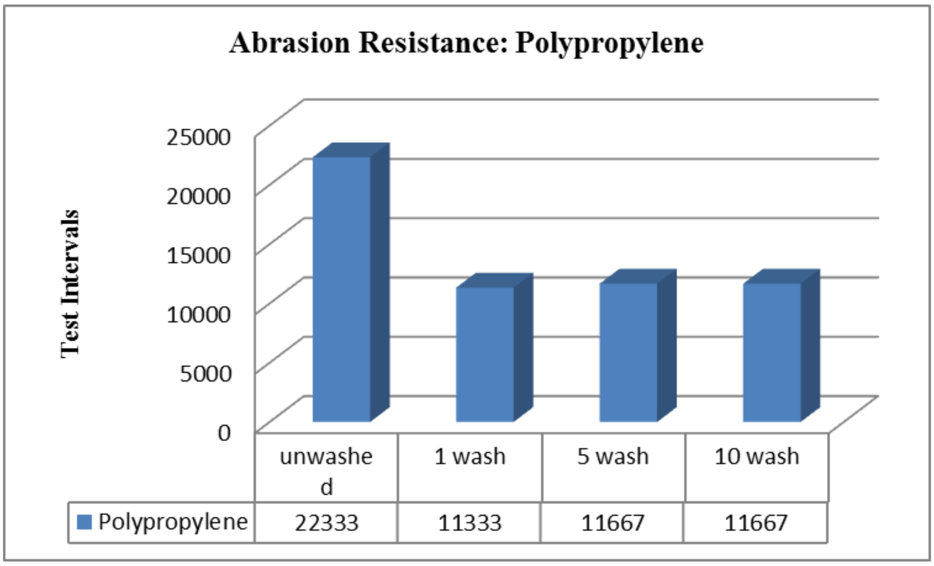


Table 4.41 Abrasion Resistance: Polypropylene.

Figure 4.42 Polypropylene breakdown

Closer examination of photographs taken while testing, shown in Figure 4.43 shows, from top to bottom, unwashed, 1 wash, 5 wash and 10 wash samples showing changes after only 5,000 test cycles.

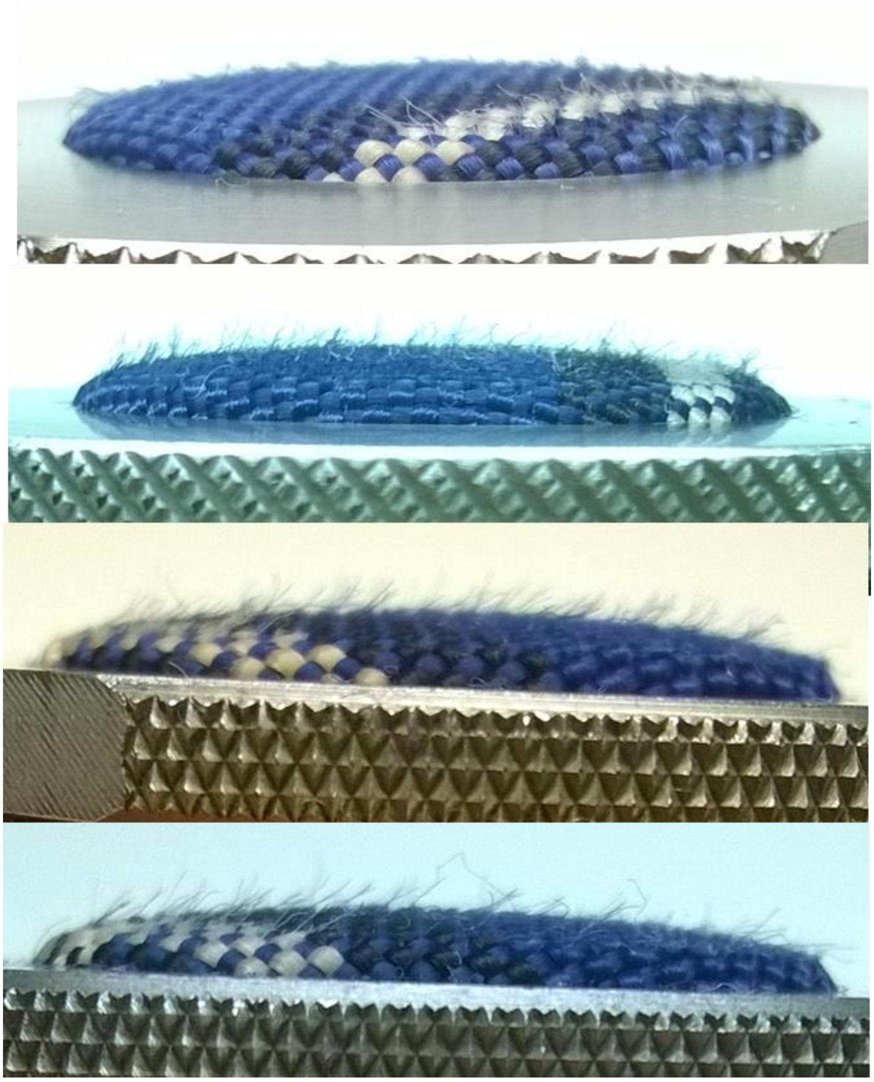


Figure 4.43 Polypropylene after 5,000 test cycles

When the results are combined, as shown in Table 4.44 the superior performance of the texturised nylon contrasts markedly with the poor abrasion resistance of the polypropylene.

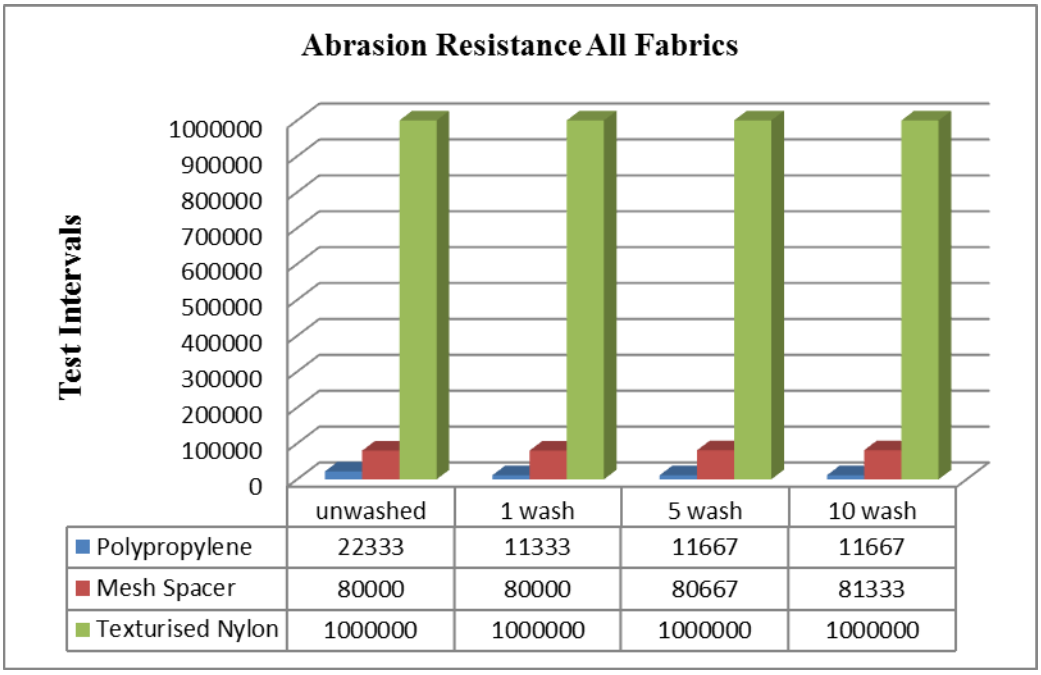


Figure 4.44 Abrasion resistance comparison of all three fabrics

4.6 Summary of Test Results.

There follows a review of the results on all the textiles that underwent testing. Although testing took considerable time the results prove that this was worthwhile as testing showed which textiles had all the properties required to take forward into full product development.

4.6.1 The Commercial Calf Jacket

The commercially available calf jacket performed very poorly on wash testing. The plan to consider modifying this existing product to save design and development time was not possible as it was imperative that the end product was robust enough to withstand high temperature washing. Concern is expressed in Section 5.21 about the thermal properties of the insulating layer causing overheating as well as the suitability of the overall design fitting the animals. The wash test served to confirm that the commercial jacket would not be suitable for use for the product being developed. Fabric testing was carried out although only minimal samples could be gathered from one jacket. The wash test and fabric test results indicate that other fabrics are more suitable for the bovine product being developed.

4.6.2The Polypropylene Fabric

This fabric performed well in wash tests and best of all fabrics in the strength tests. It worked well when stitched and bound to the mesh spacer fabric lining. Although there was evidence of some seam pucker and wrinkling on washing it would have been within an acceptable range of dimensional change if no other fabrics were available for the product. It was only when abrasion resistance was tested that it became clear that this was an area of weakness for this textile, even in its unwashed state the structure broke down readily. Despite good results in all other tests, the lack of good abrasion resistance meant that this textile would not be suitable to make into animal garments that were likely to be abraded against pens and floor in daily use.

4.6.3 The Texturised Nylon Fabric

This textile out performed all others. Strength testing was acceptable, abrasion resistance was exceptional, wash testing showed minimal dimensional change and when stitched and bound to the mesh spacer fabric testing showed that the two fabrics were compatible and worked well together. Although a few test results went over or under the range expected, this was discussed with the manufacturer who advised that it was common to find occasional lack of consistency in fabric quality. However, given the very good outcome of testing in general, and the fact that the manufacturer was aware of this quality issue and was actively addressing this, the texturised nylon was the fabric of choice for the product. Abrasion resistance testing offered proof of the durability of the fabric. Testing was stopped at 1 million test cycles as the fabric showed minimal wear and this degree of testing was far beyond the requirements of the product being developed. Aesthetically, the texturised nylon had a better look and feel compared to the polypropylene fabric.

4.6.4 The Mesh Spacer Fabric

The 3D warp knitted mesh spacer fabric performed well in all tests. Its compatibility with both the polypropylene and texturised nylon fabrics ensured that it would be suitable for use with either fabric. This fabric performed well in wash testing, maintaining its shape and structure with minimal dimensional change. In abrasion testing, although not performing as well as the texturised nylon it still withstood over 80,000 test intervals which is more than twice that expected in very hard-wearing fabrics. Considering that this fabric would be used to line the product and not subjected to the same punishment as the outer fabric, and also as it had performed well in wear trials, this was chosen as the product lining.

CHAPTER 5 – DEVELOPMENT OF THE BOVINE PRODUCT

5.1 The Harness

At the start of the project, both a harness and a garment were considered as possible supports for the faeces collection bag, and a harness was made using padded webbing, shown in Figure 5.1 There were immediate concerns with using the padded webbing as the edges were very difficult to finish and the straps were also very bulky. There was only one retail supplier found for the padded strapping, and that would have made manufacture costly. Together with comments from animal care staff who had identified problems with the harnesses they currently used and shown in Appendix A, it was decided that to pursue a harness option would not address the issues that the project had been tasked with finding a solution for. In the first week of the project, it was decided to take forward a garment design and not carry on with any harness development.

Figure 5.1 Padded webbing harness.

5.2 Calf Jacket

The decision was taken to design a calf jacket on to which a collection bag would be fixed. The very first design used Nylon 100g rip-stop waterproof coating with a sports mesh lining as shown in Figure 5.2. The collection bag would fix onto a strengthened strap across the back of the jacket and the garment would be secured around the front and girth areas with velcro.

Figure 5.2. First calf jacket

5.2.1 Commercially Available Calf Jackets

A commercially available calf jacket, shown in Figure 5.3., was evaluated for use. Had it been suitable for modification, it would have saved much design and development time. On inspection though, there were a number of reasons why the commercial jacket would not fit in with the requirements of the product being developed:

- Heating: The commercial product had a thermal insulating layer for warmth. It was not necessary to warm the animals, in fact it was important to allow air to circulate between the garment and the animal's coat so they did not sweat.

- Incompatible materials: The nylons and polyester fabrics used in the commercial product shrink at different rates and on wash testing the garment became misshapen and unsuitable for use.

Figure 5.3. Commercially available calf jacket

- Fastenings: Plastic side clips were used as fastenings and animal care staff had already indicated that they did not favour these as they were liable to break, see Figure 5.4. Additionally, the clips used on the commercial jacket were far too large in proportion to the rest of the garment.

Figure 5.4. Large side clips on the commercial jacket, left and broken clip, right.

5.3 Calf Jacket Design

The commercial jacket that had been evaluated was essentially a miniature version of a horse rug. The animals that the calf jacket would be used on are anatomically different across the back and hind quarters, having less fullness. A horse sketch and calf silhouette found online [78,79], shown in Figure 5.5. show the differences.

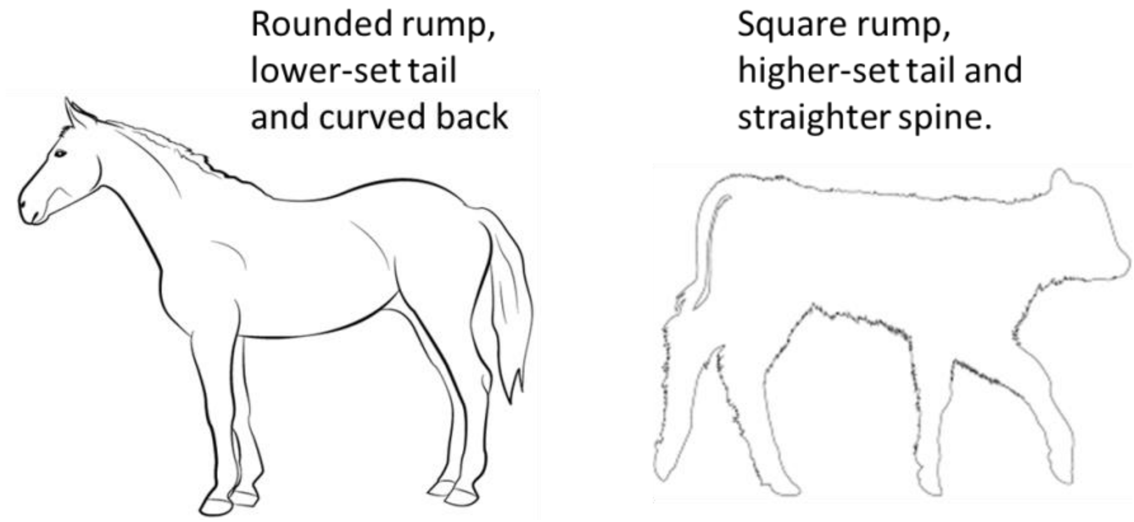


Figure 5.5 difference between equine and bovine anatomy

5.3.1 The Jacket Fabric

As the manufacturer involved in the project provided a choice of fabrics that could be used it was decided to work with three fabrics initially. The first that was chosen was a 3d warp-knit mesh spacer fabric that should be able to meet the needs of the lining layer. A plain weave polypropylene fabric as used for a well-known, quality brand of horse rugs, and a texturised nylon fabric with a polyurethane coated backing that was used in body armour, would be evaluated and tested to find out if either or both were suitable as the outer layer of the jacket. Scrap fabric would be used to make up the first calf jackets until the sizing and shape was finalised and while the chosen fabrics were tested.

5.3.2 Calf Jacket First Fit

A basic jacket was made of scrap fabric, shown in Figure 5.6 and fitted on a young calf to check the fit of the garment and the positioning of the front, girth and fillet straps.

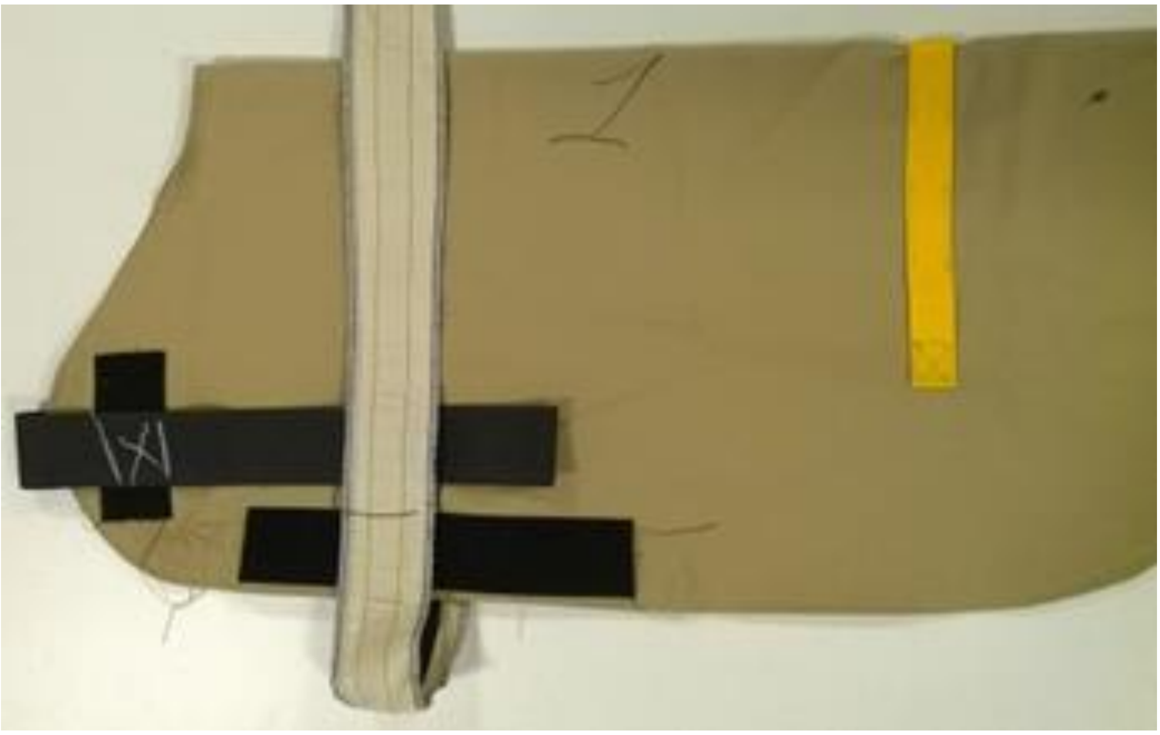


Figure 5.6 first jacket made to check fit and position of fastenings.

On a visit to the manufacturer, the **Mo**dular **L**ightweight **L**oad-carrying **E**quipment, or 'molle', method was shown which is ideal for use on the calf jacket. It is used primarily in defence apparel and consists of rows of webbing stitched to garments, e.g. body armour, to enable pouches, pockets and accessories to be easily attached. This is shown in Figure 5.7 and was an ideal way to attach the collection bag to the jacket as it allows maximum flexibility towards achieving a good fit.

Figure 5.7 the Molle system, with yellow strap attached.

The measurements taken then allowed the first calf jackets to be made up. As the fabrics were still being tested one was made from polypropylene lined with the mesh spacer fabric, see Figure 5.8 and the other was made from the texturised nylon fabric lined with the mesh spacer fabric.

Figure 5.8. Polypropylene and mesh spacer calf jacket.

A visit to the research establishment allowed assessment to be made of the calf shape to be fitted. There was no need to accommodate a rounded rump area, so darts would not be required on the rear of the jacket. The back edges of the jacket were rounded rather than square, as the edges would be bound, this would make manufacture easier. The front was shaped to fit along the shoulder with a velcro strap chosen to secure the edges across the front. This would enable the jacket to be fitted and removed quicker than using buckles or side fasteners. When these jackets were tried on, it became clear that the fillet strap, as shown in Figure 5.9, which might have been useful to secure the collection bag onto, was liable to ride up and rub the animal’s hind quarters. As this could have caused irritation and rubbing of the skin, it was decided to remove the fillet strap.

Figure 5.9 A fillet strap

Feedback from the animal care staff indicated that they were concerned about the velcro used. Velcro is rarely used on its own as it loses its integrity when in contact with hair and grass which clogs both the hook and loop side, as shown in Figure 5.10

Figure 5.10 Velcro with hair and hay after 24 hours of wear trial.

On the smallest of animals, the jacket had been worn overnight. It stayed in place despite the animal lying down which was good, as it confirmed the design fitted well.

Although the low profile velcro didn't catch as much hair in it as regular velcro did, the loop side crumpled up as can be seen in Figure 5.11 and was then difficult to fix to the hook side while wearing gloves. This was also difficult to pull through from one side of the animal, under its belly to the other side, as it had no weight to it. The animal care worker had to feel under the belly of the animal for the free edge of the velcro, and as disposable gloves are worn and tactile sense is lost, animal care staff indicated that the velcro strap on its own was difficult to locate. The jackets were easier and quicker to put on than the current harness and the animals were calm whilst they had them on. There was no evidence of damp / sweating on the coat after being removed.

Figure 5.11 Crumpled and twisted velcro after 24 hours of use

The manufacturer suggested using a low profile velcro that has less pronounced hooks and loops, a scanning electron microscope (SEM) picture at 50x magnification shows the shorter T profile of the hooks in Figure 5.12 along with a much reduced entrapment of hair.

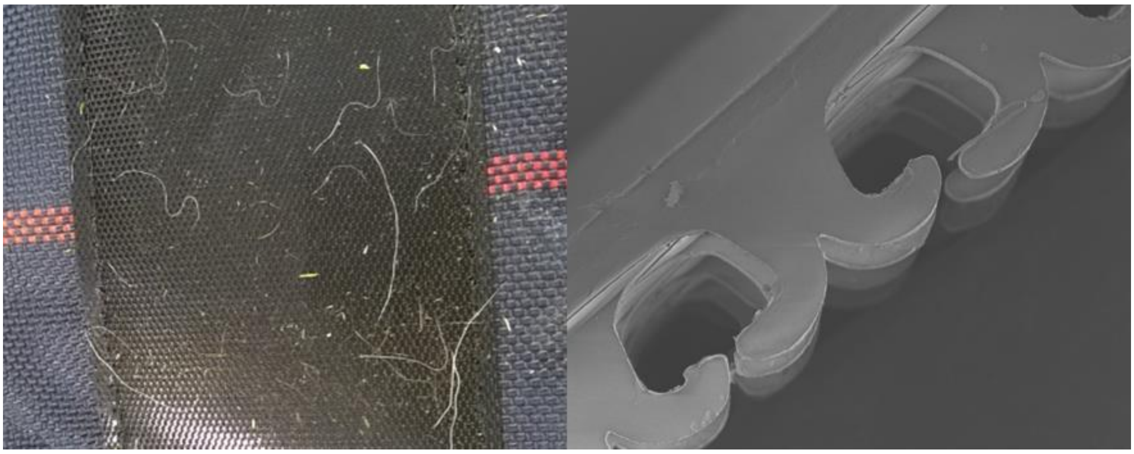


Figure 5.12 Low profile velcro trapping less hair, left and SEM picture at 50x magnification of hooks, right.

Safety of animal care staff had to be considered. The older calves have considerably more bulk/weight than the new-borns, and it was important to take this observation seriously because if staff had to bend down between the fore and hind legs of the animal to reach through to retrieve the girth strap then they were at risk of being kicked or trampled. It was vital that the girth strap could be easily passed under the animal to be fastened. Disposable gloves are essential personal protective equipment (PPE) but result in reduced tactile sensation and the single layer of velcro on its own was too difficult to locate easily by touch.

This visit also gave the opportunity to try the jackets on larger calves to establish the dimensions of a larger size. The calves wearing the jackets were the oldest ones seen. It was clear as shown in Figure 5.13 that a large as well as a small size of jacket was needed, and that the shape needed to change particularly around the hind quarters and the front. The fillet strap across the back would have to be much lower, or removed completely and replaced with leg straps that fitted round the legs. Different shape profiles were considered as in Figures 5.14 and 5.15.

Figure 5.13. Large as well as small size jacket needed.

Figure 5.14 different profiles were considered.

Figure 5.15 different profile required for the larger size

The fillet strap was replaced with a D ring, shown in Figure 5.16 to fasten on the leg straps from the collection bag.

Figure 5.16 The fillet strap removed and D ring attached

5.4 Collection Bag

The existing collection bag, shown in Figure 5.17 used by the institute leaked frequently causing loss of sample and also caused irritation to the calf's skin from spillage. The level of leaking and spillage meant that the risk of exposure to, and contamination with, pathogens to staff when removing the bag was high. The bag being used in the existing system was not held securely against the animal's skin. An outer bag had a rigid circular loop on the top and this fastened on to the harness. A plastic bag was placed inside this bag, and pulled over the edge of the outer bag, to collect the sample and as it was not close fitting the sample could be lost if the animal lay down.

Figure 5.17 the original collection bag.

The rectal area on cattle is bony and undulating. Therefore, the collection device at its interface with the animal had to achieve a close fit to reduce leaks and sample loss. In the cattle product one or two sizes would suffice.

Extensive fitting and wear trials were not possible, given that the product was being made to be used with livestock. This necessitated filming and photography which could be reviewed as many times as needed rather than repeated visits to fit new designs onto the animals themselves. The use of a scale model of the target area shown in Figure 5.18, for the smaller sizes of collection bag was made to enable the fit/curve around the rim of the collection bag to be as accurate as possible and to ensure that the tail could be accommodated. There were no proportionately accurate calf models available at the time of this project, so it was necessary to work around these limitations and take account of the considered experience and opinions of the animal care staff in the development of the bovine product.

Figure 5.18 Scale model of bovine ‘target area’

5.4.1 Collection Bag Development

Reference was made to stoma products. In some cases of illness and disease in humans, it is necessary to remove part or all of the large or small bowel. The person undergoing this type of surgery cannot then go to the toilet to empty their bowels normally. Removal of solid waste happens by making an opening in the abdomen. This opening is called a stoma. The person with a stoma cannot control the movement of the bowel and it is necessary to cover the opening with a bag to collect the waste products as they are expelled. Examples of stoma bags are shown in Figure 5.19. As stoma bags collect human waste through an incision/tube in the abdomen, they and have many of the same requirements that the animal products would need. They have to fit closely and contain the waste without leaks. The human skin though is smoother than an animal's coat and a simple adhesive device can be used to great effect. A two-part device consists of a 'flange' that adheres to the skin and has a circular clip onto which a collection bag is clicked in place. The flange can remain in place over a number of days while collection bags can be changed as frequently as needed. This seemed a good idea for the animal product so the adhesive 'flange' from a human product was tried on a calf but failed to adhere at all. It was decided to explore the application of a similar two-part device as well as the development of an improved version of the collection bag that was currently in use.

Figure 5.19 click and connect stoma products

5.4.2. The Funnel Device

In considering the stoma products that had been tried, but proved to be unsuitable for animal use, a funnel device, shown in Figure 5.20 was fashioned from 2 disposable drink cups. This gave a ridge that could accommodate both a fixing strap and an elasticated band to hold the sample collecting bag in place. The advantage of the funnel system was that it would fit the immediate target area, result in little spillage of sample and be relatively cheap to produce as any dies made for injection moulding could be modified from existing disposable cup moulds. A prototype was made easily but served to highlight the greatest challenge with this type of collection device that was the accommodation of the tail. The anal opening on cattle sits directly below the tail, and without a small space to sit the rim of the collecting device, there was a risk of loss of sample. The tail itself would also rub on the edge of any rim and ridge and on further consideration of the shape of the funnel – type collection device; the circular shape would have to be changed to a more oval shape to sit better in the anatomical landscape of the target area.

Figure 5.20 The funnel device.

5.4.3 Developing the Curve

Returning to the existing collection bag, it was clear that the main problem with its shape was that of fit. The ideal collection bag would surround the rectum, accommodate the tail and conform to the curve of the animal’s rear at all points to reduce sample loss. Using flat boning bent round and attached to itself at a 45° angle gave a curve that would fit better around the target area see Figure 5.21. The problem of accommodating the tail was still a concern, however by making the curve from two pieces of boning with both ends attached at a 45° angle, a normative linear curve fitted the target area precisely and could be placed over the tail, improving the fit of the collection bag.

Figure 5.21 the final curve on the left and the first curve on the right.

5.4.4 Further Bag Development

There were two main requirements of the bag: it had to fit the target area and hold an inner, disposable sample collection bag in place. The first prototype appeared flat as shown in the top left of Figure 5.22, even though the boning inserted into it formed a curve. The solution was to draft the bag with a curved edge, as shown in Figure 5.22 top right and bottom.

Figure 5.22 flat edge of the bag, top left, new pattern shape, top right and made-up new bag shape bottom picture.

The folded edge, accommodating the curved boning then proved difficult to stitch without causing roping of the seam. It was decided to simplify the manufacturing process here and instead of a double turn hem to overlock the edge allowing a single turn hem to be made. This reduced the twist of the seam, reduced the difficulty in forming the hem, yet would not affect the performance of the bag. Additionally, extra snap fasteners were added to the edge of the bag to enable the disposable inner collection bag to be fixed in place securely. In the original bag, the inner bag was only folded over the edge, leading to sample loss. Figure 5.23 shows these changes in place.

Figure 5.23. Clips to hold the inner disposable collection bag in place.

5.5 First Jacket and Bumbag Fitting

The first fit of the jacket and bumbag together as shown in Figure 5.24, was very successful. The jacket appears comfortable to wear. The calves that tried it on were calm during fitting and while wearing it. The bumbag too was attached easily with no signs of distress or discomfort during fitting or wear.

Figure 5.24 First fitting of jacket with collection bag attached

Modifications required at this stage were:

- Have poppers fasten on the underside of the strap instead of on top to avoid leaving a flap that the calves could pull.
- Tighten and shorten the leg straps, perhaps try strong elastic with strong poppers.
- The D ring that the leg strap fastens on to was in a single position allowing no adjustment – perhaps attach 3 at different spacings to allow a wider range of calf sizes to be accommodated.
- The Molle strip across the back, in Figure 5.25 that the bumbag fastens onto, have one or two more strips, one as placed on the existing jacket, one nearer the edge and one nearer the centre, this would give maximum flexibility in fitting.

Figure 5.25 Increase 1 molle strip across the back to 2 or 3

The large and small sizes of jacket, shown in Figure 5.26, were made after this first complete fitting.

Figure 5.26 small and large calf jackets.

5.6 Final Choice of Fastenings

Development of the fastening system began by looking at what is currently used in animal clothing. Horse blankets and rugs use a range of different fastenings including surcingles, clasps, buckles and leather, plastic, webbing and elastic strapping. Calf jackets available commercially use webbing and plastic side clips. Velcro is also commonly used in combination with other fastenings. As the bovine product will have to withstand washing at high temperatures neither leather, nor a vinyl based leather substitute, is suitable.

The very first prototype of the calf jacket shown in Figure 5.27, included a reinforced strip of polypropylene webbing into which plastic D rings on thinner polypropylene webbing straps were stitched.

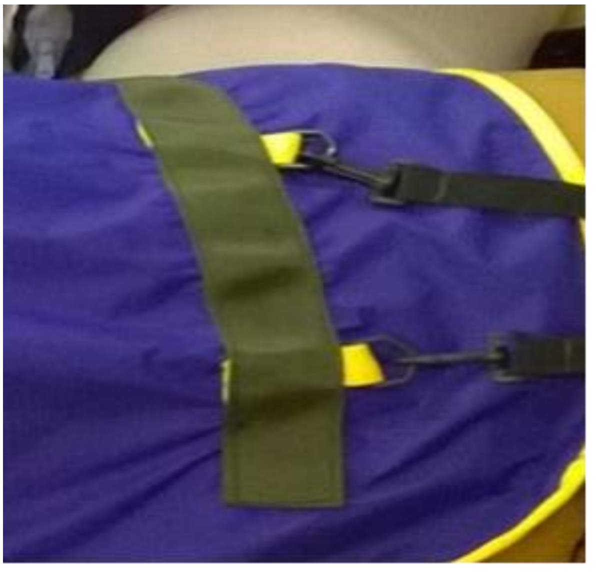


Figure 5.27 First prototype with webbing straps and D rings

5.6.1 Fastening Methods

Traditional fastenings include buckles and surcingle sets as shown in Figure 5.28

Figure 5.28 buckle on left and surcingle set on right

Buckles were ruled out as the polypropylene strapping that would be used has to be melted on any cut edge, and as holes would have to be punched for the bail of the buckle to fit through, this would make a point of weakness on the strap. The commercial jacket used side clips as in Figure 5.29 for fastening, and these were also used on the original harness, but were known to break when in use and also when in the wash.

Figure 5.29 side clip

Similarly D rings and clip hooks, shown in Figure 5.30 were not favoured by animal care staff as they too were known to break.

Figure 5.30 D ring and clip hook

Snap fasteners, shown in Figure 5.31 offered a quick to apply in use, yet strong fastening and velcro, as shown in Figure 5.32. also offered a quick to open and close fastening.

Figure 5.31 Snap fastener

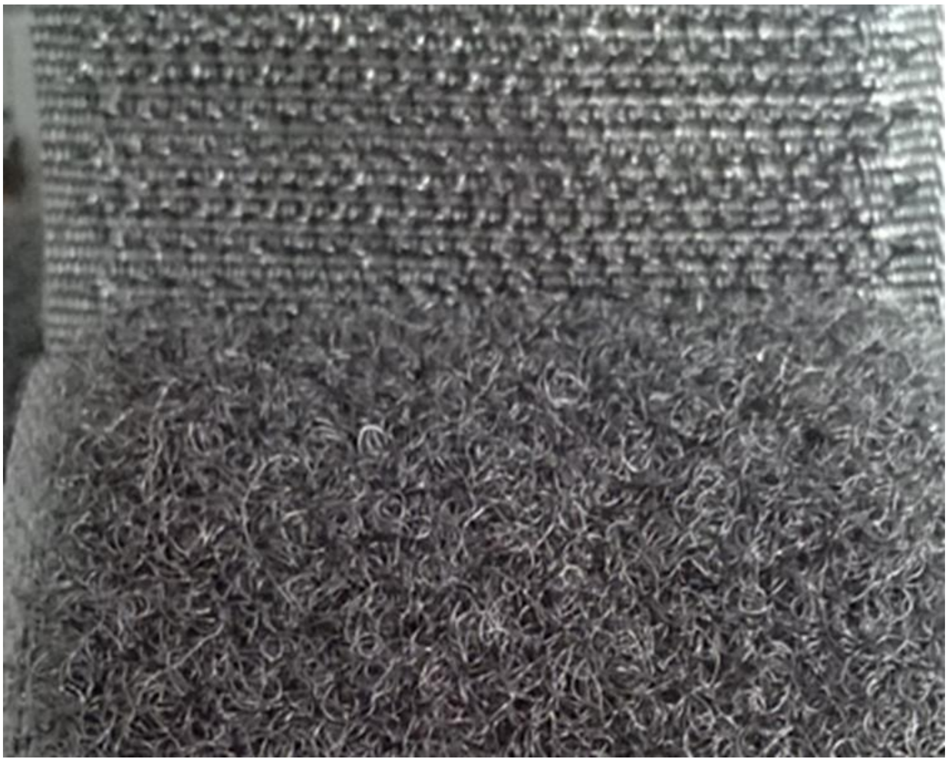


Figure 5.32 “Velcro” hook and loop touch-close fastener

5.7 Wear Trial Assessment

After the first fitting of the jacket and collection bag together, much consideration was given to all aspects of the jacket, taking account of observations made at fittings and discussions with animal care staff. At this point, many changes were made to move towards finalising the jacket design. It had become clear after testing that one of the jacket fabrics performed better than the other so all jackets were made of this fabric from this point. It was agreed to keep the velcro fastening at the front, but back it with jacket fabric and bind the edges to give it more stability, this is shown in Figure 5.33

Figure 5.33 Changes to front velcro fastening.

Some different fastenings around the girth were made up and evaluated during fitting on calves so animal care staff could choose the one they found the best to use see Figure 5.34 This included a more substantial velcro strap, a surcingle with elastic strap and a strap with snap fasteners.

Figure 5.34 velcro, left, surcingle, centre and snap fastener, right.

It was also suggested that two molle strips were placed across the back of the jacket to give more adjustment options for fitting the collection bag. The D ring that had been placed on the outside of the jacket was moved to the inside and increased to three instead of just one to also give more adjustment potential. When these jackets went for a wear trial it was clear that only minor changes were needed to complete the design. The favoured girth fastening was the surcingle, the front fastening would remain velcro as it worked well since being reinforced with a fabric backing, and one more molle strip was added across the back. The final jacket is shown in Figure 5.35

Figure 5.35 The final jacket

5.8 Limitations of Product Development

There were limitations to the amount of development work that could be undertaken on the project. The product design, the fabric chosen and then the wear trials all had to take place within a year which is a relatively short space of time to develop a product from concept to market.

5.8.1 The Product Design

Ideally three or four designs could have been trialled. For the larger size of calf jacket especially, some alternative shapes, shown in Figures 5.12 and 5.13, were briefly considered. The final shape that was taken forward into production was simple in its design and this made it easier to manufacture. The larger size was simply scaled up and this is shown in Figure 5.26.

5.8.2 The Textiles Chosen

Textiles provided by the manufacturer involved in the project were tested and used to make up the first garments for wear trial. They were found to be suitable for the product being developed, and therefore no further work was done to search for, identify and test other fabrics that might have also been appropriate to use. Some investigation was carried out on commercially available calf jackets to establish the textiles used and their suitability, and these were found to be less robust than the manufacturer-provided textiles made available to the project.

CHAPTER 6 - THE DOG PRODUCT

A secondary requirement of the project brief was to design a dog product to collect faeces for emergency care. The product will be a disposable, single use item used in a veterinary setting peri-operatively and for collecting samples and also used during end of life care when managing continence is important. This product utilised the research completed for the bovine bumbag to design a canine version. Whilst there are many hundreds of patent and patent applications for contraptions to collect dog faeces [80] there are currently no commercially available products other than dog nappies. The opinion of a vet and animal rescue centre manager was sought and investigation into textile pet products and their wash care was undertaken.

6.1 Markets for the Product

Two important considerations were veterinary approval, and control of how the product is used and sold. Due regard has to be given to the possibility that a collection device might be used by unscrupulous pet owners to avoid having to take their dogs out for normal exercise and toileting. This product should therefore be used under veterinary guidance and has been developed as a medical device rather than a pet accessory. Although it might limit product sales, there has to be a degree of responsibility shown in promoting this product for managing fecal continence under specific conditions. Without taking this into account, animal welfare organisations may take action to restrict sales of, or ban a product that they believe discourages dog owners from taking proper care of their animals. This product should be marketed through veterinary surgeries to introduce an element of control of its appropriate use. It should be recommended for use peri-operatively and during end of life care. There may be some specialist uses, for example in zoological settings, for show dogs and perhaps in some transport settings. It would be beneficial to its reputation, if the dog product had some form of supply control to ensure it is used appropriately, and that is the rationale for suggesting it is considered a medical device under veterinary control.

6.2 Discussion with Veterinary Practitioner

The situations in which fecal incontinence occurs was discussed with a qualified veterinary practitioner. See the transcript of the discussion in Appendix B This discussion confirmed that peri-operative use and end of life care are two significant situations where dogs can either lose control of their bowel or may not be able to exercise and toilet normally, either due to sedation or through debility. Maintaining a clean environment is important. As is the need in general day to day pet care to ensure that pet bedding is cleaned at a high enough temperature to kill pathogens that can both re-infect pets or worse, infect their human companions. A list of zoonotic infections is given in table 1 and these include many commonly occurring organisms present that include toxoplasmosis, giardia, toxicara and parasites like worms.

6.3 Discussion with Animal Shelter Manager

The dog product and its appropriate use was discussed with Lee Ann Leckie, manager at the Borders Pet Rescue Centre. A transcript of the discussion is shown in Appendix C. She was able to confirm that a product used inappropriately, where dog owners applied a collection device rather than take their animals out for walks and allow normal toileting behaviour, would lead to the product being banned as it would be encouraging neglect of the animals' natural needs for exercise and normal toileting behaviour. She was also able to identify that the product may have a use in collecting samples for analysis and diagnosis.

6.4 Dog Nappies

Dog nappies as shown in Figure 6.1 are widely available from pet stores and online, and although it might be possible to design a better fit, the problem with a nappy type product is that for all but the most liquid faeces, then dog waste would be held against the skin and also the coat which could lead to skin irritation and also give the owner additional cleaning and handling of faeces to keep the dog clean. It is important that the dog product has veterinary recommendation so for these reasons a nappy type product is not suitable.

Figure 6.1 dog nappy

6.5 Development of the Dog Product

There are many points to consider in the development of a canine collection product. Comfort, safety and functionality are the prime considerations. The bovine bumbag had to consider protection of staff from exposure to harmful microorganisms and it is necessary to also consider that the user of the dog product will be handling dog faeces. The government give advice in its code of practice for the welfare of dogs [81], and that advises that a pet dog has " regular opportunities to exercise" and also that it is provided with "an appropriate place it can use as a toilet". It also advises on the likelihood of contracting illnesses and diseases from pets as there is also a risk to pet owners of illness and infection transmitted via dog faeces [82].

The bovine bum bag uses a jacket to which a collection bag is attached. This is unsuitable for dog use as dogs are much more flexible and active than cattle. Other issues where dog use differs to bovine use include some dogs having thick coats which might cause overheating in a centrally heated house. There would also have to be a large range of sizes produced to accommodate the vast array of length, height and width of both recognised dog breeds and non – pedigree dogs.

A lightweight t-shirt style dog coat with back opening is a new product being used after surgery instead of a plastic cone placed round the dog's neck. This is more comfortable, particularly for the smaller breeds. This was considered for adaptation and Figure 6.2 shows a 'Suitical' dog coat which was bought for evaluation:

Figure 6.2 'Suitical' recovery suit

The Suitical recovery suit covers the entire body of the dog. In smaller breeds it looks suitable but in production, adding cuffing around the neck and leg holes would be impossible in the very smallest toy or 'teacup' breeds and at the other end of the range, the amount of fabric required to accommodate the largest breeds could require over 2 metres of fabric. Not only would many different sizes have to be made, but the price range would also have a large variation. Additionally, the product would need regular washing without other household laundry at high temperatures to maintain hygiene.

Another consideration is that the suitical product is a substantial garment to manufacture, it is made from 4 different fabrics and requires 4 different machines to produce it as illustrated in Figure 6.3 making it very expensive to manufacture. On evaluation, this covers the whole body area and the product being developed is only required to collect faeces.

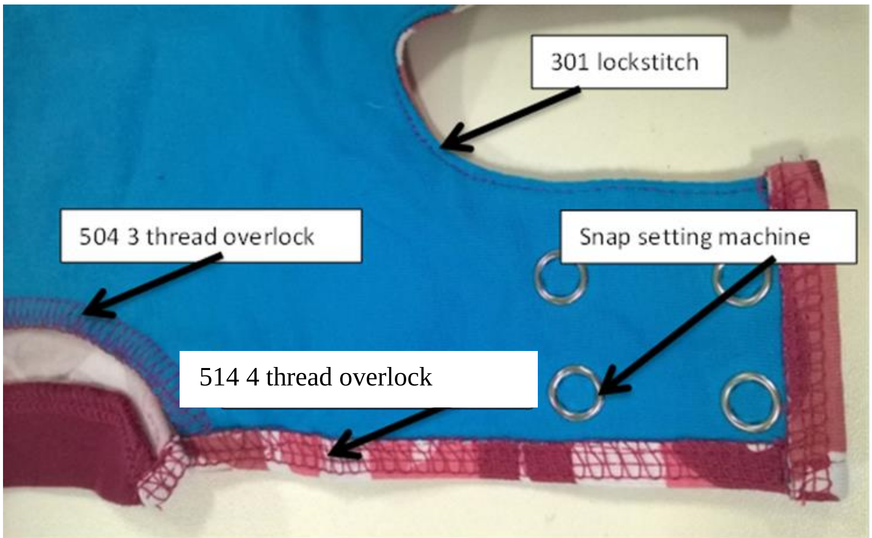


Figure 6.3 suitical, showing machines required to make product

A re-useable product must also be fully washable at a high temperature to ensure disinfection from harmful pathogens. An investigation into pet products at low, medium and high prices shows that although prices range from a few pounds to over a hundred pounds, washing and care instructions are basic with most fabrics recommended to be washed at 30° or 40°. The suitical product care label in Figure 6.4 reflected this. This is of great concern as disinfection generally doesn't start until temperatures over 60° are reached and then maintained for some time .[84] As households are increasingly washing at lower temperatures [85] it may result in a product that does not get properly cleansed from harmful organisms including bacteria and parasites (Table 2.1, Section 2.3) These commonly occurring pathogens may re-

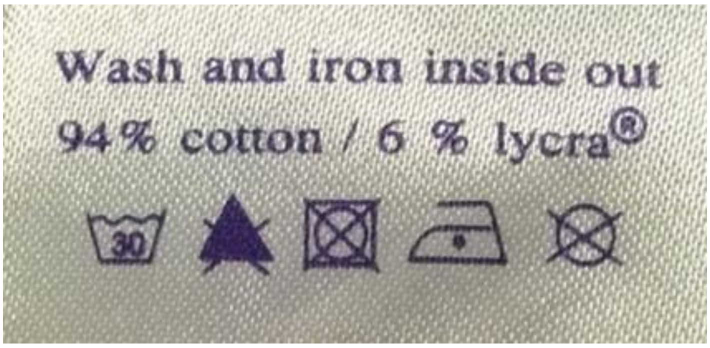


Figure 6.4 Suitical wash label

infect a pet or worse, expose members of the family to harmful microorganisms that may lead to illness.

Notably, a dog's body temperature normal range is 38°C – 39.2°C, so it is reasonable to assume that any pathogens that survive on the animal at this temperature would also withstand washing at 30°C to 40°, the washing temperature that most pet products recommend. Many dog owners wash pet products along with bedding and towels and this must surely increase the risk of contamination and exposure to family members who themselves may be vulnerable through young or old age or as a result of acute or chronic illness or disease. Considering these barriers to maintaining a clean, germ free product was the reason behind deciding to work towards developing a disposable single-use product. This can ensure a clean or sterile product to begin with and takes away the risks associated with poor after care. The challenges were sourcing suitable materials that are robust enough to withstand animal use but cost effective enough to produce in bulk that will sell at an affordable price.

6.6 Design of the Product

Having discounted the use of a jacket with attached collection bag as in the bovine bum-bag, and also a Suitical type of dog coat/clothing, the key features of the product were that it is disposable to reduce exposure to pathogens to pets and pet owners, that its design is minimal to keep production costs down and that as well as obvious requirements like comfort for the animal and functionality, the product should be easy to apply and remove. Additionally, there was a need for the product to have flexible sizing as there is a wide variation in dog sizes and shapes. By focusing on only collecting faeces, as urine collection would require more than one design, due to the anatomical differences between dogs and bitches, the first step is to understand the anatomy of the canine form, especially around the hip and lower spinal area to achieve a means of fitting a collection device that will stay in place and also distribute weight (from faeces) evenly without dislodging the product.

A Figure of eight strapping was the initial design, Figure 6.5 shows the strapping fitting around the hind legs and meeting or fixing at a centre point behind the tail.

Figure 6.5 Figure of eight strap

Buttonholes were used initially with the plan to insert straps with snap fasteners as shown in Figure 6.6

Figure 6.6 Buttonholes and straps with snaps

Snap fasteners were incorporated into the strap as in Figure 6.7.

Figure 6.7 Strap with snap fasteners

A panel was then introduced to sit behind the tail area and into which the leg straps could be secured. One end of the strap was fixed with the other end offering a means of fitting to the individual dog's measurement. Figure 6.8 shows the panel and also how the flexible strap at this point was changed to popper tape.

Figure 6.8 popper tape with panel above tail

Popper tape is a soft cotton tape with snap fasteners attached at regular intervals. Figure 6.9 shows the plastic snap fasteners placed every 2.5 cm. to attach the collection bag are clearly seen.

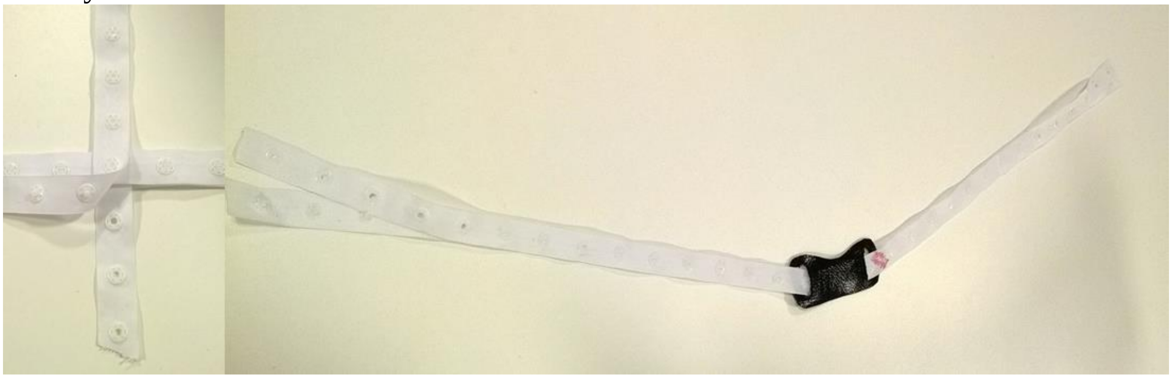


Figure 6.9 continuous popper tape with panel

A regular dog bag can be attached by opening the snap fasteners and securing the bag in place by snapping the fastener shut with the bag in between and this is shown in Figures6.10 and 6.11.

Figure 6.10 Popper tape fastened in place with bag attached.

Figure 6.11 The tape and collection bag placement.

The panel into which the tape is fastened was developed by trialling a number of different materials. The consideration for this component were that is had to be fairly rigid, soft around the edges it required two apertures into which the tape would be secured and this might offer an area of weakness. The fabrics and construction methods used in developing the bovine product were considered further to identify whether any were suitable for the dog product, to take the development forward towards a more robust prototype. The Molle system used on the calf jackets as a means of attaching the collection bags, and shown in Figure 6.12 was found to work well.

Figure 6.12 Molle strap

The free end of the popper tape was secured with a bar tack as shown in Figure 6.13, and the dog product began to look more marketable. The final version of the product is shown in Figure 6.14

Figure 6.13 tape secured with bar tack

Figure 6.14 Final Product

It is understood that offering a sterile product would gain additional acceptance of it as a medical device. To ensure that the tapes used would withstand a high temperature wash and autoclaving, which sterilises with steam under pressure, the product was both washed on a 92° wash 5 times and autoclaved to ensure that although this is essentially a disposable product, it could withstand heat treatment. And could therefore be re-useable where suitable cleaning facilities existed. Figure 6.15 shows all three samples. These show little if any visible change. Also for manufacturing purposes, if it was to be presented as a sterile product, it may be cheaper to sterilise the product through autoclaving than by irradiation.

Figure 6.15 Popper tape with top, unwashed, middle, 5 wash and bottom, autoclaved.

6.7 Wear Trial of the Dog Product

A short trial was completed at the end of the project to show the working prototype in place on a number of different sizes and types of dog, Figures 6.16 – 6.18.

Figure 6.16 Alsatian cross

Figure 6.17 Retriever

Figure 6.18 small cross breed.

Dog owners commented on the ease of use and simple design and the dogs that took part did so without any obvious anxiety or distress. The elderly dog in particular seemed unconcerned and lay down with no signs of discomfort.

CHAPTER 7 - CONCLUSION AND RECCOMMENDATIONS FOR FURTHER RESEARCH AND DEVELOPMENT

This was a challenging project in terms of the broad range of knowledge required to enable the development of two marketable products. The fundamental core skill was a sound understanding of the qualities of textiles, in particular man-made filaments/materials, in order to ascertain the most suitable combination that were fit for the purpose of developing a functional garment with faeces collection bag for use with livestock, and a faeces collection device for dogs that did not impinge on any design of the many thousands of already patented devices. All aims and objectives were met and two products were produced.

7.1 Project Summary

All project objectives were met:

- *Design improved harness/garment systems to support faeces collection bags*.

  A calf jacket was designed in two sizes with three sizes of interchangeable collection bags. The development of this is shown in Chapter 5.

- *Design 2 layer faeces collection bag system with 'water' proof seals and easy/ hygienic removal of inner bag.*

  The collection bag was designed to conform to the animal's body/rear-end and secure fixing points for the collection bags were attached to reduce sample loss. The development of the collection bag is shown in Section 5.4.

- *To source suitable materials for all elements of designs.*

  A commercially available calf jacket was tested but proved unsuitable. The manufacturer, J&D Wilkie provided fabrics used in body armour. Fabrics were tested as outlined in Chapter 3, with results shown in Chapter 4. A 3D warp knitted mesh spacer fabric was chosen to line the calf jacket as this gave added comfort by allowing air to circulate between the garment and the animal, the risk of overheating could be avoided. The outer fabric, a texturised nylon, was chosen for its exceptional abrasion resistance, good strength and tear strength as well as good high-temperature wash performance. These two chosen textiles along with suitable trim and fittings made the bovine product.

- *Manufacture and evaluate prototype systems.*

  Working with the production team at J&D Wilkie, prototypes of the calf jackets and collection bags were made. Calves were observed on four occasions. Development notes were made based on observations and feedback from animal care staff. Changes to the design of the jacket, including trials of different fastenings and alterations to the collection bag to optimise its fit were passed to the manufacturer who made the suggested alterations until the final combination that worked best was found.

- *Develop optimised prototypes and final design of a complete faeces collection system for calves.*

  The prototypes made went forward for wear trials and subsequent changes were made until the final, most efficient and functional design was found. This process is detailed in Chapter 5.

- *Consult with vets, dog owners and others involved in dog care to establish design criteria for a faeces collection system for dogs.*

A veterinary practitioner, an animal shelter manager and a number of dog owners were consulted to collect information that aided the design of the dog product. The development of this product is outlined in Chapter 6.

- *Develop first prototypes of a faeces collection system for dogs*.

  Prototypes were developed and tried on dogs of different sizes. The prototypes are shown in a selection of photographs in Section 6.6.

- Publicise new products.

  The Bovine and canine products were launched at an event held at Moredun Research Institute on 25th June 2017. A poster representing the development of the bovine product was prepared for the Veterinary and Animal Parasitology (VAAP) conference held in Malaysia in September 2017

7.1.1The Bovine Bumbag.

Research into textiles, particularly in the area of coatings including hydrophobic nano coatings for example, may offer further possibilities in the development of a product used in a research environment where it is important to ensure exposure to pathogens is managed to protect both staff and animals. In manufacturing the product, further work should be undertaken in manufacturing the product to optimise the production process to bring down both the time taken and the cost of making the calf jackets and collection bags. The cutting efficiency of the lay plan was not covered during the project but it is envisaged that the manufacturer will undertake this task. Improved efficiency reduces waste by making better use of the way the garment pieces are cut from the raw materials. The researcher was mindful of this during the design process but it was not a requirement of the brief or a specific objective of the project.

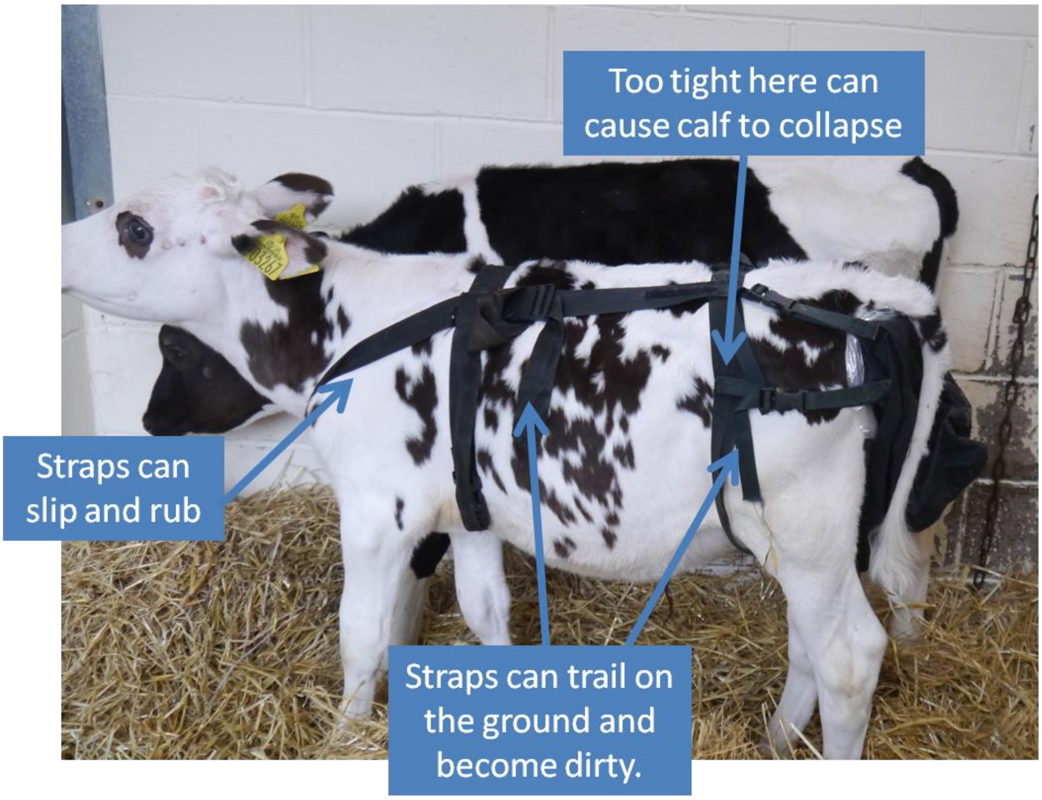
7.1.2 The Dog Product

The requirement of the project was the design of a dog product. The extended time given (by changing to part-time study), enabled further work to be carried out and the design to be taken to the working prototype stage. There are still many aspects of the dog product to be considered, primarily trials using it under its intended use conditions, peri-operatively and at end of life care. It was not possible within the project timescale to take the dog product any further. A single product was developed to be sized up and down to cater for all sizes of dog. Further research could identify changes to the overall design that may be required for very large or very small dogs.

Appendix A

Project Brief

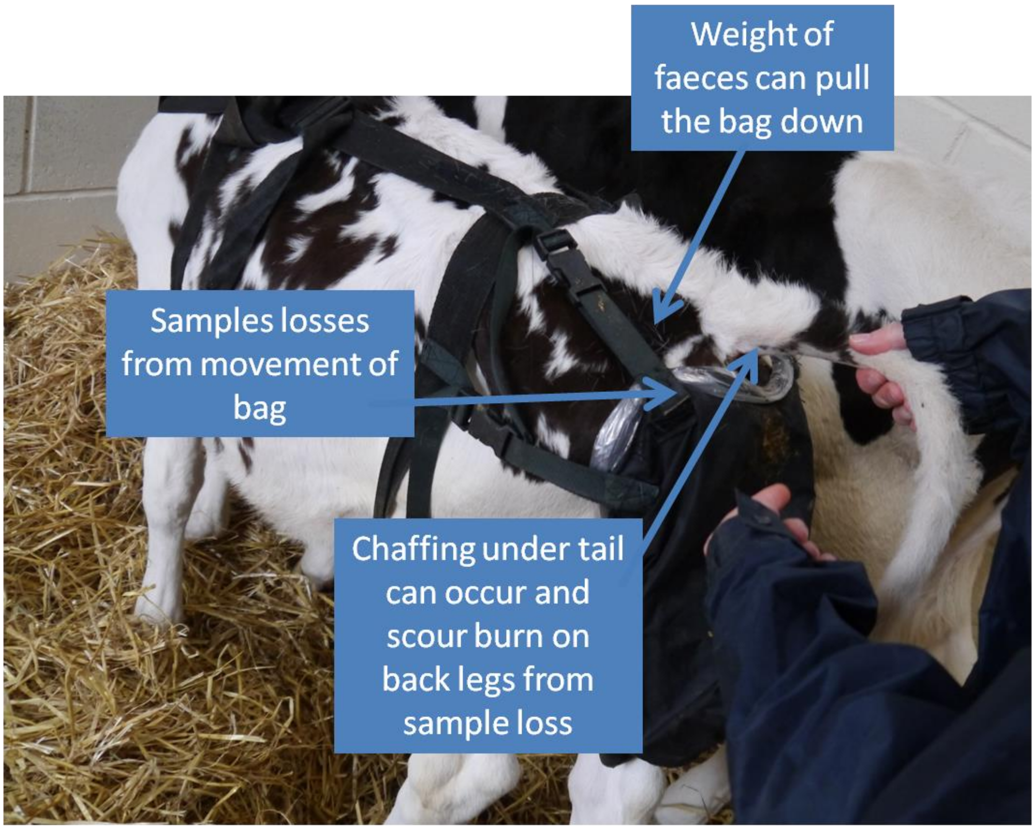
The aim of the proposed project is to develop and test novel products for the hygienic collection of faeces from livestock. Faecal collection is routinely carried out by research scientists to collect several types of parasitic organisms as a first step in the development of new treatments. No commercial products are available for this, hence the current method uses harnesses and bags which were developed in house at the Moredun Research Institute (MRI), many decades ago, using materials which were easy to source, but are not ideally suited to the task. There are several issues with the current system including sample losses of up to 50%, health and safety concerns regarding the handling of faeces by staff, issues with the bag collection system not being in the correct position and becoming contaminated, issues with the current webbing harness becoming tangled and/or dirty and discomfort for the animals.



The project aims to design, prototype and evaluate a new system for faeces collection. The new system will have:

- A durable harness or garment that comfortably fits the calf, can fit a range of different sized calves without trailing straps and provides secure fixing points for the sample collection bags.
- An outer collection bag that is securely fixed to the harness/garment, protects the tail from chaffing (caused by the collection bag rubbing against the tail) and 'burning' (caused by prolonged contact between fluid faeces and the skin). The outer collection bag will have an opening that provides access to the inner sample collection bag.

- The inner collection bags will be disposable and compostable and will be attached to the outer, supporting, collection bag using a fastening/seal system that we will design during this project. This new system will enable the inner collection bags to collect 100% of faeces without contaminating the outer bag or staff member.
- Once developed for calves the design/products will be modified for use in dogs and these will be evaluated by relevant stakeholders.



This project presents a number of unusual technical challenges:

- We need an extraordinarily robust 'garment' or harness that will fit the calf comfortably and can expand to fit the growing animal, without trailing straps, whilst holding the significant weight of excrement at the rear of the animal without sagging.
- We need to ensure a 'water' resistant seal between the inner collection bag and the products that support it.
- We need to ensure that the inner bag can be removed easily without losing any of the sample or contaminating the sample collector.
- We need to adapt our designs for use in dogs, the main issues we will need to address in this part of the project include: dogs like to sit so the bag system will need to be tethered in such a way that it doesn't get in the way of sitting, dogs don't like to have things touching their rear area, so the product will need to be very soft, thin and designed for minimum contact pressure. We also have options for what the bag system would be designed to contain: faeces, urine, vaginal discharge during 'heat' or all 3, this would affect bag volume, position and the possible inclusion of absorbent fibres to contain liquids. We may also

consider including a deodorising element if this would be considered beneficial to dog/owner.

Successful, completion of this project will significantly reduce the amount of time calves need to be kept for sample collection, improving the efficiency of all future research projects involving faeces collection. Health and safety concerns around staff handling faeces containing harmful and potentially infectious organisms will be significantly reduced and animal welfare should be significantly improved. There are many research and commercial organisations around the world who undertake work similar to that conducted at the Moredun Institute and there are several online discussion fora for discussing potential improvements to the ‘home’ made sample collection systems currently used but to date no other textile organisation has been involved or attempted to address these issues and no commercial product exists.

The project will also develop and evaluate first prototypes of an equivalent system for dogs. There is a perceived need among some vets, pet shops and dog owners for a product that could be used to maintain a clean in-door environment while caring for sick or elderly dogs that are incontinent or dogs in heat. Many pet owners need to leave their animals while working, etc. even if their pet is sick, old or in heat. At the moment the only products available to such owners are nappy type products but these have limited liquid capacity, are only suitable for smaller breeds and by holding the excrement or discharge against the dogs skin/fur there is a requirement for regular washing of the dog. We anticipate the potential market for such a product being large and will work on finding suitable routes to market during the project. It is intended that JD Wilkie would manufacture and distribute the developed products.

Currently around 100,000 dogs are admitted to veterinary hospitals and practices each year in the UK with severe gastroenteritis, which presents a significant problem in maintaining hygienic kennels for other patients and health and safety issues for staff. The use of this type of harness could significantly reduce the labour costs and improve health and safety in veterinary practices in these cases. We have spoken to a number of vets some of whom agreed strongly that there is a need for the proposed product. However, others were satisfied with their current methods of caring for dogs in these circumstances and were focussed on the difficulties associated with designing a suitable product, we intend to consult with both groups of vets during the process as the more negative comments could be very useful in setting the design criteria. We have specifically selected to work on calves, in the first instance, as calves have many similarities to dogs: cattle have hair, instead of wool; they have tails and calf faeces tends to be soft and similar to diarrhoea in consistency.

During the course of the project contact will be made with a range of potential end-users of both the bovine and canine products to develop a greater understanding of potential commercialisation routes. For example, opinions will be sought from companies that may be interested in the bovine product such as Moredun Scientific Limited, Ridgeway Scientific Limited and Universities in the UK and Europe (e.g. Universities of Bristol, Glasgow, Liverpool, Berlin, and Naples). We will also endeavour to contact other groups who may be interested in the collection of faecal material from livestock e.g. livestock food manufacturers. For the canine product we will contact a range of Veterinary Practices, the Royal College of Veterinary Surgeons, pet shops and professional dog service providers (such as dog clothing manufacturers, dog groomers, dog walkers) to explore potential markets.

It is envisaged that the project will consist of 5 phases. In phase 1, researchers at Heriot-Watt University (HWU) will research potentially suitable materials for all elements of the new system, prepare multiple novel designs, using state-of-the-art materials to replace the current harnesses and bags. In phase 2, these designs will be examined by experienced scientists at MRI and product development specialists at J&D Wilkie's (JDW). The most promising designs will be carried forward for prototyping at JDW before being tested at MRI on a small number of calves (phase 3) all materials will then be laboratory tested and designs and materials will be optimised (and redesigned as appropriate) before developing the final prototype. Phase 3 will also establish the design criteria for the dog product and will develop suitable contacts for the evaluation of the product and potential route to market. The outcome of the project is aimed to be a final design of the bovine product suitable for commercial manufacture which will be a better fit for the calves, significantly reduce wastage, and hence the need for experimental animal use, as well as improve staff safety by reducing contact with potentially infectious faeces. The second outcome of the project will be first prototypes and a suitable network of interested stakeholders for the canine product. The bulk of the project will be carried out by researchers at HWU who will use expertise in textile engineering and design to develop and evaluate the functionality of ideas in the laboratory, staff at JDW will be responsible for manufacturing prototypes to ensure their commercial viability and prototypes will be 'field-tested' at MRI, who are the initial expected customers for the end product and have extensive knowledge of sampling collection methods and constraints.

In addition to the commercial realisation of the final product, findings from the project are expected to be presented by researchers from MRI and HWU at academic and industry conferences, with the intention of demonstrating to the wider research and veterinary industry the benefits of the final product.

Immediately on completion of the project we anticipate having product ready for manufacture that will address the needs of the research institutes and manufacturers of bovine drugs and immunisations, this will have immediate impact on the efficiency of their collection procedures and safety of their employees.

Appendix B

Discussion with veterinary practitioner

Transcript of meeting between Lesley Cherrie (LC) and Priscila Bordes (PB) a veterinary practitioner.

LC: How useful would a faeces collection product be peri-operatively and at end of life care?

PB: There are many situations where a dog can lose control of its bowels and bladder. It could be as a result of nerves in an anxious animal, a the result of an accident or injury or due to one of many diseases that can affect the autonomic nervous system and cause previously continent animals to lose control of the ability to toilet normally. Some forms of sedation can also result in incontinence of the bowels or bladder. A simple to use device that was easy for staff to apply and remove as well as comfortable for the animal would be very useful.

LC: Are there other situations where a faeces collection product might be useful?

PB: There may be a zoological use for other animals, especially when sedated. The collection of faeces and urine samples can be quite challenging, and a collection product may have a use in this situation also.

LC: Do you think dog owners are aware of the possibility of zoonotic infection?

PB: No. Many people treat their dogs like children, and are not aware of the pathogens that can be passed from animal to human and the illness or parasites like toxoplasmosis, giardia and worms for example that can be shared from pets to their owners and family.

LC: Do you think dog owners are aware of the need to wash pet textiles at a hot temperature to kill off micro-organisms and reduce the likelihood of infection or re-infection to pets or humans?

PB: I think that dog owners should be advised of the need to wash pet textiles appropriately. I don’t know for sure though who should be responsible for disseminating that information though. Perhaps the product manufacturers should take more responsibility. I do know that many dog owners wash their pet textiles alongside other household laundry, and this should be discouraged.

Appendix C

Transcript of meeting between Lesley Cherrie (LC), and Lee-Ann Lackie (LAL), manager at Borders Pet Rescue

LC: You often work with dogs that have been poorly cared for. What continence issues can they have?

LAL: Some dogs may not have been house-trained but it is important to rule out infection or disease. The dog product may help to obtain urine and/or waste samples for analysis to establish if there are any underlying reasons why a dog may be incontinent. An animal may come into the shelter pregnant, the product again may help obtain a sample for testing without causing undue stress to the animal or frustration for the staff that have to collect samples for testing.

LC: When is there likely to be issues with continence other than peri-operatively or at end of life care?

LAL: Animals that are very nervous will sometimes pass urine and defecate, but we work to ensure that animals leaving the centre have had time to get used to socialising with people and other animals and in most cases that nervous response diminishes with time and care.

LC: Can you think of any situations where a device that collects faeces can be used other than peri-operatively and at end of life care?

LAL: Just for obtaining samples for testing, it could be really useful for that. It might be used in some transport situations like flying.

LC: Should it be sold as a pet accessory or a medical device?

LAL: A medical device. In the wrong hands, it might be used by unscrupulous pet owners in place of taking their dogs outside to toilet normally. If it is easy to put on and take off again, it might attract people who will use it inappropriately. A medical device could at least be available through vets or maybe also animal welfare organisations. This would make sure that people knew how and when to use it properly and would control who could get the device.

LC: Thank you for your help. I would like to ask two related questions. Zoonoses are infections that can spread from pet to owner. How many owners do you think understand the possibility of this?

LAL: Probably none. I don’t think people know this.

LC: The majority of pet bedding products advise washing at 30°C or 40°C. These temperatures will not kill micro-organisms and parasites. Who do you think should be responsible for advising pet owners of this?

LAL: I don’t know. I don’t think any one person or group. Maybe everyone involved with dogs and who make dog things should be responsible.

Appendix D

Maximum force and elongation test results

Mesh Spacer

Mesh Spacer Warp	Maximum Extension Warp (mm)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	90	90	89	90	88	89.4	0.9	1.0	0.4	88.6	90.2
1 wash	97	91	106	108	94	99.2	7.5	7.5	3.3	92.5	105.9
5 wash	98	82	89	100	85	90.8	7.9	8.7	3.5	83.7	97.9
10 wash	99	92	96	96	100	96.6	3.1	3.2	1.4	93.8	99.4

Table AA Mesh Spacer Maximum Extension Warp

Mesh Spacer Weft	Maximum Extension Weft (mm)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	149	146	143	147	143	145.6	2.6	1.8	1.2	143.3	147.9
1 wash	170	171	165	184	168	171.6	7.3	4.3	3.3	165.1	178.1
5 wash	191	179	178	194	162	180.8	12.7	7.0	5.7	169.5	192.1
10 wash	167	180	177	170	177	174.2	5.4	3.1	2.4	169.3	179.1

Table AB Mesh Spacer Maximum Extension Weft

Mesh Spacer Warp	Maximum Force Warp (N)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	830	810	820	820	820	820.0	7.1	0.9	3.2	813.7	826.3
1 wash	820	740	820	820	860	812.0	43.8	5.4	19.6	772.8	851.2
5 wash	920	710	920	890	870	862.0	87.6	10.2	39.2	783.7	940.3
10 wash	900	890	870	780	860	860.0	47.4	5.5	21.2	817.6	902.4

Table AC Mesh Spacer Maximum Load Warp

Mesh Spacer Weft	Maximum Force Weft (N)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	740	750	740	760	730	744.0	11.4	1.5	5.1	733.8	754.2
1 wash	620	660	680	710	650	664.0	33.6	5.1	15.0	633.9	694.1
5 wash	710	690	750	820	630	720.0	70.7	9.8	31.6	656.8	783.2
10 wash	620	720	770	730	770	722.0	61.4	8.5	27.5	667.1	776.9

Table AD Mesh Spacer Maximum Load Weft

Maximum Force and elongation (extension): Mesh Spacer fabric

Warp Knit spacer fabric SAMPLE	Condition	Direction	Maximum Extension	Maximum Load	Mean extension	Mean load
1	unwashed	warp	90	830		
2	unwashed	weft	149	740		
3	unwashed	warp	90	810	Warp	
4	unwashed	weft	146	750	**89**	**820**
5	unwashed	warp	89	820		
6	unwashed	weft	143	740		
7	unwashed	warp	90	820	Weft	
8	unwashed	weft	147	760	**146**	**740**
9	unwashed	warp	88	820		
10	unwashed	weft	143	730		
11	1 wash	warp	97	820		
12	1 wash	weft	170	620		
13	1 wash	warp	91	740	Warp	
14	1 wash	weft	171	660	**99**	**810**
15	1 wash	warp	106	820		
16	1 wash	weft	165	680		
17	1 wash	warp	108	820	Weft	
18	1 wash	weft	184	710	**172**	**660**
19	1 wash	warp	94	860		
20	1 wash	weft	168	650		
21	5 washes	warp	98	920		
22	5 washes	weft	191	710		
23	5 washes	warp	82	710	Warp	
24	5 washes	weft	179	690	**91**	**860**
25	5 washes	warp	89	920		
26	5 washes	weft	178	750		
27	5 washes	warp	100	890	Weft	
28	5 washes	weft	194	820	**181**	**720**
29	5 washes	warp	85	870		
30	5 washes	weft	162	630		
31	10 washes	warp	99	900		
32	10 washes	weft	167	620		
33	10 washes	warp	92	890	Warp	
34	10 washes	weft	180	720	**97**	**860**
35	10 washes	warp	96	870		
36	10 washes	weft	177	770		
37	10 washes	warp	96	780	Weft	
38	10 washes	weft	170	730	**174**	**720**
39	10 washes	warp	100	860		
40	10 washes	weft	177	770		

Polypropylene

Polypropylene Warp	Maximum Extension (mm)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	74	73	69	75	70	72.2	2.6	3.6	1.2	69.9	74.5
1 wash	70	68	46	51	65	60.0	10.8	18.0	4.8	50.3	69.7
5 wash	69	70	70	68.5	69.5	69.4	0.7	0.9	0.3	68.8	70.0
10 wash	66	69	65	69	60.5	65.9	3.5	5.3	1.6	62.8	69.0

Table AE Polypropylene Maximum Extension Warp

Polypropylene Weft	Maximum Extension (mm)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	60.5	54	53	54	52	54.7	3.3	6.1	1.5	51.7	57.7
1 wash	47.5	44	67	68	52	55.7	11.1	20.0	5.0	45.7	65.7
5 wash	53.5	57	59	55.5	56.5	56.3	2.0	3.6	0.9	54.5	58.1
10 wash	59	58.5	52	49.5	56	55.0	4.1	7.5	1.9	51.3	58.7

Table AF Polypropylene Maximum Extension Weft

Polypropylene Warp	Maximum Force (N)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	2100	2100	2200	2200	2300	2180.0	83.7	3.8	37.4	2105.2	2254.8
1 wash	2200	2200	1800	2000	2100	2060.0	167.3	8.1	74.8	1910.3	2209.7
5 wash	2200	2300	2200	2200	2200	2220.0	44.7	2.0	20.0	2180.0	2260.0
10 wash	2100	2300	2200	2300	2200	2220.0	83.7	3.8	37.4	2145.2	2294.8

Table AG Polypropylene Maximum Load Warp

Polypropylene Weft	Maximum Force (N)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	1900	1900	2000	2000	2000	1960.0	54.8	2.8	24.5	1911.0	2009.0
1 wash	1900	1900	2100	2100	1800	1960.0	134.2	6.8	60.0	1840.0	2080.0
5 wash	2000	2000	2100	2000	2100	2040.0	54.8	2.7	24.5	1991.0	2089.0
10 wash	2000	2100	2000	1900	2000	2000.0	70.7	3.5	31.6	1936.8	206.32

Table AH Polypropylene maximum Load Weft

Maximum Force and elongation (extension): Polypropylene fabric

Polypropylene Fabric SAMPLE	Condition	Direction	Maximum Extension	Maximum Load	Mean extension	Mean load
1	unwashed	warp	74	2100		
2	unwashed	weft	60.5	1900		
3	unwashed	warp	73	2100	Warp	
4	unwashed	weft	54	1900	**72**	**2200**
5	unwashed	warp	69	2200		
6	unwashed	weft	53	2000		
7	unwashed	warp	75	2200	Weft	
8	unwashed	weft	54	2000	**54.5**	**2000**
9	unwashed	warp	70	2300		
10	unwashed	weft	52	2000		
11	1 wash	warp	70	2200		
12	1 wash	weft	47.5	1900		
13	1 wash	warp	68	2200	Warp	
14	1 wash	weft	44	1900	**60**	**2100**
15	1 wash	warp	46	1800		
16	1 wash	weft	67	2100		
17	1 wash	warp	51	2000	Weft	
18	1 wash	weft	68	2100	**55.5**	**2000**
19	1 wash	warp	65	2100		
20	1 wash	weft	52	1800		
21	5 washes	warp	69	2200		
22	5 washes	weft	53.5	2000		
23	5 washes	warp	70	2300	Warp	
24	5 washes	weft	57	2000	**69.5**	**2200**
25	5 washes	warp	70	2200		
26	5 washes	weft	59	2100		
27	5 washes	warp	68.5	2200	Weft	
28	5 washes	weft	55.5	2000	**56.5**	**2000**
29	5 washes	warp	69.5	2200		
30	5 washes	weft	56.5	2100		
31	10 washes	warp	66	2100		
32	10 washes	weft	59	2000		
33	10 washes	warp	69	2300	Warp	
34	10 washes	weft	58.5	2100	**66**	**2200**
35	10 washes	warp	65	2200		
36	10 washes	weft	52	2000		
37	10 washes	warp	69	2300	Weft	
38	10 washes	weft	49.5	1900	**55**	**2000**
39	10 washes	warp	60.5	2200		
40	10 washes	weft	56	2000		

Texturised Nylon

Texturised nylon Warp	Maximum Extension (mm)					mean	SD	%CV	SE	Lower CI	Upper CI
Unwashed	97	96	96	98	101	97.6	2.1	2.1	0.9	95.7	99.5
1 wash	104	112	107	99	107	105.8	4.8	4.5	2.1	101.5	110.1
5 wash	119	113	120	107	106	113.0	6.5	5.8	2.9	107.2	118.8
10 wash	118	115	112	122	122	117.8	4.4	3.7	2.0	113.9	121.7

Table AI Texturised nylon Maximum Extension Warp

Texturised nylon Weft	Maximum Extension (mm)					mean	SD	%CV	SE	Lower CI	Upper CI
Unwashed	98	108	106	101	108	104.2	4.5	4.3	2.0	100.2	108.2
1 wash	114	107	109	103	97	106.0	6.4	6.0	2.9	100.3	111.7
5 wash	114	105	113	101	113	109.2	5.8	5.4	2.6	104.0	114.4
10 wash	113	115	117	112	111	113.6	2.4	2.1	1.1	111.4	115.8

Table AJ Texturised nylon Maximum Extension Weft

Texturised nylon Warp	Maximum Force (N)					mean	SD	%CV	SE	Lower CI	Upper CI
Unwashed	1800	1800	1700	1900	1100	1660.0	320.9	19.3	143.5	1372.9	1947.1
1 wash	1800	1900	1900	1800	1900	1860.2	54.8	2.9	24.5	1811.0	1909.0
5 wash	2000	2000	2000	1800	1800	1920.0	109.5	5.7	49.0	1822.0	2018.0
10 wash	1900	1900	1900	2000	2000	1940.0	54.8	2.8	24.5	1891.0	1989.0

Table AK Texturised nylon Maximum Load Warp

Texturised nylon Weft	Maximum Force (N)					mean	SD	%CV	SE	Lower CI	Upper CI
Unwashed	1900	1200	1200	1100	1200	1320.0	327.1	24.8	146.3	1027.4	1612.6
1 wash	1300	1300	1300	1300	1200	1280.0	44.7	3.5	20.0	1240.0	1320.0
5 wash	1300	1200	1300	1200	1300	1260.0	54.8	4.3	24.5	1211.0	1309.0
10 wash	1300	1300	1300	1300	1300	1300.0	0.0	0.0	0.0	1300.0	1300.0

Table AL Texturised nylon Maximum Load Weft

Maximum Force and elongation (extension): Texturised Nylon fabric

Texturised Nylon Fabric SAMPLE	Condition	Direction	Maximum Extension	Maximum Load	Mean extension	Mean load
1	unwashed	warp	97	1800		
2	unwashed	weft	98	1900		
3	unwashed	warp	96	1800	Warp	
4	unwashed	weft	108	1200	**98**	**1700**
5	unwashed	warp	96	1700		
6	unwashed	weft	106	1200		
7	unwashed	warp	98	1900	Weft	
8	unwashed	weft	101	1100	**104**	**1300**
9	unwashed	warp	101	1100		
10	unwashed	weft	108	1200		
11	1 wash	warp	104	1800		
12	1 wash	weft	114	1300		
13	1 wash	warp	112	1900	Warp	
14	1 wash	weft	107	1300	**106**	**1900**
15	1 wash	warp	107	1900		
16	1 wash	weft	109	1300		
17	1 wash	warp	99	1800	Weft	
18	1 wash	weft	103	1300	**106**	**1300**
19	1 wash	warp	107	1900		
20	1 wash	weft	97	1200		
21	5 washes	warp	119	2000		
22	5 washes	weft	114	1300		
23	5 washes	warp	113	2000	Warp	
24	5 washes	weft	105	1200	**113**	**1900**
25	5 washes	warp	120	2000		
26	5 washes	weft	113	1300		
27	5 washes	warp	107	1800	Weft	
28	5 washes	weft	101	1200	**109**	**1300**
29	5 washes	warp	106	1800		
30	5 washes	weft	113	1300		
31	10 washes	warp	118	1900		
32	10 washes	weft	113	1300		
33	10 washes	warp	115	1900	Warp	
34	10 washes	weft	115	1300	**118**	**1900**
35	10 washes	warp	112	1900		
36	10 washes	weft	117	1300		
37	10 washes	warp	122	2000	Weft	
38	10 washes	weft	112	1300	**114**	**1300**
39	10 washes	warp	122	2000		
40	10 washes	weft	111	1300		

Appendix E

Tear test results

Texturised nylon Across weft	Tear Test (N)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	69	67	84	66	86	74.4	9.8	13.1	4.4	65.7	83.1
1 wash	67	68	66	70	66	67.4	1.7	2.5	0.7	65.9	68.9
5 wash	88	92	69	64	91	80.8	13.3	16.4	5.9	68.9	92.7
10 wash	89	92	68	70	69	77.6	11.8	15.3	5.3	67.0	88.2

Texturised nylon Tear Test Across Weft

Texturised nylon across warp	Tear Test (N)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	94	64	63	88	64	74.6	15.1	20.3	6.8	61.1	88.1
1 wash	88	90	88	95	97	91.6	4.2	4.5	1.9	87.9	95.3
5 wash	64	69	89	69	68	71.8	9.8	13.7	4.4	63.0	80.6
10 wash	68	66	87	93	100	82.8	15.2	18.3	6.8	69.2	96.4

Texturised nylon Tear Test Across Warp

SAMPLE **Texturised Nylon**	Condition	Direction	TEAR FORCE Mean	Mean result
1	unwashed	(Warp) across weft	69	
2	unwashed	(Weft) across warp	94	
3	unwashed	Across weft	67	Across weft
4	unwashed	Across warp	64	**74**
5	unwashed	Across weft	84	
6	unwashed	Across warp	63	
7	unwashed	Across weft	66	Across warp
8	unwashed	Across warp	88	**75**
9	unwashed	Across weft	86	
10	unwashed	Across warp	64	
11	1 wash	Across weft	67	
12	1 wash	Across warp	88	
13	1 wash	Across weft	68	Across weft
14	1 wash	Across warp	90	**67**
15	1 wash	Across weft	66	
16	1 wash	Across warp	88	
17	1 wash	Across weft	70	Across warp
18	1 wash	Across warp	95	**92**
19	1 wash	Across weft	66	
20	1 wash	Across warp	97	
21	5 washes	Across weft	88	
22	5 washes	Across warp	64	
23	5 washes	Across weft	92	Across weft
24	5 washes	Across warp	69	**81**
25	5 washes	Across weft	69	
26	5 washes	Across warp	89	
27	5 washes	Across weft	64	Across warp
28	5 washes	Across warp	69	**72**
29	5 washes	Across weft	91	
30	5 washes	Across warp	68	
31	10 washes	Across weft	89	
32	10 washes	Across warp	68	
33	10 washes	Across weft	92	Across weft
34	10 washes	Across warp	66	**78**
35	10 washes	Across weft	68	
36	10 washes	Across warp	87	
37	10 washes	Across weft	70	Across warp
38	10 washes	Across warp	93	**83**
39	10 washes	Across weft	69	
40	10 washes	Across warp	100	

Polypropylene Across weft	Tear Test (N)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	304	338	339	316	365	332.4	23.5	7.1	10.5	311.4	353.4
1 wash	202	190	195	215	221	204.6	13.1	6.4	5.9	192.9	216.3
5 wash	190	179	193	177	211	190.0	13.6	7.2	6.1	177.8	202.2
10 wash	202	202	215	220	185	204.8	13.6	6.7	6.1	192.6	217.0

Polypropylene Tear Test Across Weft

Polypropylene across warp	Tear Test (N)					mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	277	302	261	322	325	297.4	28.0	9.4	12.5	272.4	322.4
1 wash	214	220	219	183	234	214.0	18.9	8.8	8.4	197.1	230.9
5 wash	218	209	212	174	172	197.0	22.2	11.2	9.9	177.2	216.8
10 wash	177	158	190	204	228	191.4	26.6	13.9	11.9	167.6	215.2

Polypropylene Tear Test Across Warp

SAMPLE **Polypropylene**	Condition	Direction	TEAR FORCE Mean	Mean result
1	unwashed	Across weft	304	
2	unwashed	Across warp	277	
3	unwashed	Across weft	338	Across weft
4	unwashed	Across warp	302	**332**
5	unwashed	Across weft	339	
6	unwashed	Across warp	261	
7	unwashed	Across weft	316	Across warp
8	unwashed	Across warp	322	**297**
9	unwashed	Across weft	365	
10	unwashed	Across warp	325	
11	1 wash	Across weft	202	
12	1 wash	Across warp	214	
13	1 wash	Across weft	190	Across weft
14	1 wash	Across warp	220	**205**
15	1 wash	Across weft	195	
16	1 wash	Across warp	219	
17	1 wash	Across weft	215	Across warp
18	1 wash	Across warp	183	**214**
19	1 wash	Across weft	221	
20	1 wash	Across warp	234	
21	5 washes	Across weft	190	
22	5 washes	Across warp	218	
23	5 washes	Across weft	179	Across weft
24	5 washes	Across warp	209	**190**
25	5 washes	Across weft	193	
26	5 washes	Across warp	212	
27	5 washes	Across weft	177	Across warp
28	5 washes	Across warp	174	**197**
29	5 washes	Across weft	211	
30	5 washes	Across warp	172	
31	10 washes	Across weft	202	
32	10 washes	Across warp	177	
33	10 washes	Across weft	202	Across weft
34	10 washes	Across warp	158	**205**
35	10 washes	Across weft	215	
36	10 washes	Across warp	190	
37	10 washes	Across weft	220	Across warp
38	10 washes	Across warp	204	**191**
39	10 washes	Across weft	185	
40	10 washes	Across warp	228	

APPENDIX F

Dimensional stability test results

Mesh Spacer

Mesh Spacer	Dimensional Stability Top Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	365	365	365	365	0	0	0	365	365
5 wash	380	380	382	380.67	1.15	0.30	0.67	379.33	382.00
10 wash	373	382	LOST	377.5	6.36	1.69	4.5	368.5	386.5

Table A Mesh Spacer Top Left to Right

Mesh Spacer	Dimensional Stability Centre Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	360	360	360	360	0	0	0	360	360
5 wash	375	370	382	375.67	6.03	1.60	3.48	368.71	382.63
10 wash	365	373	LOST	369	5.66	1.53	4	361	377

Table B Mesh Spacer Centre Left to Right

Mesh Spacer	Dimensional Stability Bottom Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	360	362	370	364	5.29	1.45	3.05	357.89	370.11
5 wash	385	380	385	383.33	2.89	0.75	1.67	380	386.67
10 wash	375	385	LOST	380	7.07	1.86	5	370	390

Table C Mesh Spacer Bottom Left to Right

Mesh Spacer	Dimensional Stability Centre Top to Bottom (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	395	393	400	396	3.61	0.91	2.08	391.84	400.16
5 wash	400	395	396	397	2.65	0.67	1.53	393.94	400.06
10 wash	400	400	LOST	400	0	0	0	400	400

Table D Mesh Spacer Centre Top to Bottom

Mesh Spacer	Dimensional Stability Bias Top Left to Bottom Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	570	570	570	570	0	0	0	570	570
1 wash	525	535	535	531.67	5.77	1.09	3.33	525	538.33
5 wash	560	560	545	555	8.66	1.56	5	545	565
10 wash	546	545	LOST	545.5	0.71	0.13	0.5	544.5	546.5

Table E Mesh Spacer Bias Top Left to Bottom right

Mesh Spacer	Dimensional Stability	mean	SD	%CV	SE	Lower	Upper

	Bias Top Right to Bottom Left (mm)							Cl	Cl
Unwashed	570	570	570	570	0	0	0	570	570
1 wash	525	525	535	528.33	5.77	1.09	3.33	521.67	535
5 wash	540	545	438	541	3.61	0.67	2.08	356.84	545.16
10 wash	536	342	LOST	539	40.24	0.79	3	533	545

Table F Mesh Spacer Bias top Right to Bottom Left

Dimensional stability in mm Polypropylene

Polypropylene	Dimensional Stability Top Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	400	400	395	398.33	2.89	0.72	1.67	395	401.67
5 wash	385	385	390	386.67	2.89	0.75	1.67	383.33	390
10 wash	395	390	388	391	3.61	0.92	9.08	386.84	395.16

Table G Polypropylene Top Left to Right

Polypropylene	Dimensional Stability Centre Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	400	398	395	397.67	2.52	0.63	1.45	394.76	400.57
5 wash	395	385	387	389	5.29	1.36	3.06	382.89	395.11
10 wash	393	386	388	389	3.16	0.93	2.08	384.84	393.16

Table H Polypropylene Centre Left to Right

Polypropylene	Dimensional Stability Bottom Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	398	396	395	396.33	1.53	0.39	0.88	394.57	398.1
5 wash	390	392	386	389.33	3.86	0.78	1.76	385.81	392.86
10 wash	396	390	390	392	3.46	0.88	2	388	396

Table I Polypropylene Bottom Left to Right

Polypropylene	Dimensional Stability Centre Top to Bottom (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	392	400	398	396.67	4.16	1.05	2.4	391.86	401.47
5 wash	390	390	395	391.67	2.89	0.74	1.67	388.33	395
10 wash	388	390	396	391.33	4.16	1.06	2.4	386.53	396.14

Table J Polypropylene Centre Top to Bottom

Polypropylene	Dimensional Stability Bias Top Left to Bottom Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	570	570	570	570	0	0	0	570	570
1 wash	562	565	560	562.33	2.52	0.45	1.45	559.43	565.24
5 wash	550	550	560	553.33	5.77	1.04	3.33	546.67	560
10 wash	566	560	565	563.67	3.21	0.57	1.86	559.95	567.38

Table K Polypropylene Bias Top Left to Bottom right

Polypropylene	Dimensional Stability Bias Top Right to Bottom Left (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	570	570	570	570	0	0	0	570	570
1 wash	567	565	560	564	3.61	0.64	2.08	559.84	568.16
5 wash	548	548	555	550.33	4.04	0.73	2.33	545.67	555
10 wash	560	555	560	558.33	2.89	0.52	1.67	555	561.67

Table L Polypropylene Bias top Right to Bottom Left

Dimensional stability in mm Texturised nylon

Texturised nylon	Dimensional Stability Top Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	393	395	389	392.33	3.06	0.78	1.76	388.81	395.86
5 wash	383	390	378	383.67	6.03	1.57	3.48	376.71	390.63
10 wash	380	382	376	379.33	3.06	0.81	1.76	375.81	382.86

Table M Texturised nylon Top Left to Right

Texturised nylon	Dimensional Stability Centre Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	392	395	386	391	4.58	1.17	2.65	385.71	396.29
5 wash	380	382	378	380	2	0.53	1.15	377.69	382.31
10 wash	375	380	375	376.67	2.89	0.77	1.67	373.33	380

Table N Texturised nylon Centre Left to Right

Texturised nylon	Dimensional Stability Bottom Left to Right (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	393	397	389	393	4	1.02	2.31	388.38	397.62
5 wash	383	382	378	381	2.65	0.69	1.53	377.94	384.06
10 wash	379	380	378	379	1	0.26	0.58	377.85	380.15

Table O Texturised nylon Bottom Left to Right

Texturised nylon	Dimensional Stability Centre Top to Bottom (mm)			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	400	400	400	400	0	0	0	400	400
1 wash	393	381	377	383.67	8.33	2.17	4.81	374.05	393.28
5 wash	366	370	366	367.33	2.31	0.63	1.33	364.67	370
10 wash	365	369	369	367.65	2.31	0.63	1.33	365	370.33

Table P Texturised nylon Centre Top to Bottom

Texturised	Dimensional Stability	mean	SD	%CV	SE	Lower	Upper

nylon	Bias Top Left to Bottom Right (mm)							CI	CI
Unwashed	570	570	570	570	0	0	0	570	570
1 wash	542	545	536	541	4.58	0.85	2.65	535.71	586.29
5 wash	525	230	528	527.67	2.52	0.48	1.45	524.76	530.57
10 wash	526	530	523	526.33	3.51	0.67	2.03	522.28	530.39

Table Q Texturised nylon Bias Top Left to Bottom right

Texturised nylon	Dimensional Stability Bias Top Right to Bottom Left (mm)			mean	SD	%CV	SE	Lower CI	Upper CI
Unwashed	570	570	570	570	0	0	0	570	570
1 wash	550	550	547	549	1.73	0.32	1	547	551
5 wash	535	535	530	533.33	2.89	0.54	1.67	530	536.67
10 wash	526	235	529	530	4.58	0.86	2.65	524.71	535.29

Table R Texturised nylon Bias top Right to Bottom Left

Dimensional stability: Unwashed samples

Date	Time	Fabric	Top left to right	Centre left to right	Bottom left to right	Centre top to bottom	Diagonal top left to bottom right	Diagonal top right to bottom left
14/3/16	11.00	Sample 1 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 2 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 3 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 4 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 5 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 6 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 7 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 8 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 9 Polypropylene	400	400	400	400	570	570
14/3/16	11.00	Sample 1 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 2 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 3 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 4 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 5 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 6 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 7 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 8 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 9 Texturised Nylon	400	400	400	400	570	570
14/3/16	11.00	Sample 1 Mesh Filler	400	400	400	400	570	570
14/3/16	11.00	Sample 2 Mesh Filler	400	400	400	400	570	570
14/3/16	11.00	Sample 3 Mesh Filler	400	400	400	400	570	570
14/3/16	11.00	Sample 4 Mesh Filler	400	400	400	400	570	570
14/3/16	11.00	Sample 5 Mesh Filler	400	400	400	400	570	570
14/3/16	11.00	Sample 6 Mesh Filler	400	400	400	400	570	570
14/3/16	11.00	Sample 7 Mesh Filler*	400	400	400	400	570	570
14/3/16	11.00	Sample 8 Mesh Filler *	400	400	400	400	570	570
14/3/16	11.00	Sample 9 Mesh Filler	Sample lost					

* Samples 7 and 8 were replacement samples after the originals were lost.

Measurements of marked fabric samples: distances between pairs of marks after 1 wash

Date	Time	Fabric	Top left to right	Ccentre left to right	Bottom left to right	Centre top to bottom	Diagonal top left to bottom right	Diagonal top right to bottom left
14/03/16		Sample 1 Polypropylene	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	400	400	398	392	562	567
		% change	0	0	-0.5	-2	-1.4	-0.5
14/03/16		Sample 5 Polypropylene	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	400	398	396	400	565	565
		% change	0	-0.5	-1	0	-0.9	-0.9
14/03/16		Sample 9 Polypropylene	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	395	395	395	398	560	560
		% change	-1.3	-1.3	-1.3	-0.5	-1.8	-1.8
14/03/16		Sample 1 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	393	392	393	393	542	550
		% change	-1.8	-2	-1.8	-1.8	-4.9	-3.5
14/03/16		Sample 5 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	395	395	397	381	545	550
		% change	-1.3	-1.3	-0.8	-4.8	-4.4	-3.5
14/03/16		Sample 9 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	389	386	389	377	536	547
		% change	-2.8	-3.5	-2.8	-5.8	-6	-4
02/06/16		Sample 1 Mesh Spacer	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	365	360	360	395	525	525
02/06/16		% change	-8.8	-10	-10	-1.3	-7.9	-7.9
02/06/16		Sample 5 Mesh Spacer	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	365	360	362	393	535	525
02/06/16		% change	-8.8	-10	-10	-1.8	-6.1	-7.9
02/06/16		Sample 8 Mesh Spacer	400	400	400	400	570	570
02/06/16		Measurements after 1 wash	365	360	370	400	535	535
		% change	-8.8	-10	-7.5	0	-6.1	-6.1

Measurements of marked fabric samples: distances between pairs of marks after 5 washes

Date	Time	Fabric	Top left to right	Ccentre left to right	Bottom left to right	Centre top to bottom	Diagonal top left to bottom right	Diagonal top right to bottom left
14/03/16		Sample 2 Polypropylene	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	385	395	390	390	550	548
		% change	-3.8	-1.3	-2.5	-2.5	-3.5	-3.9
14/03/16		Sample 6 Polypropylene	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	385	385	392	390	550	548
		% change	-3.8	-3.8	-2	-0.8	-1.8	-2.6
14/03/16		Sample 7 Polypropylene	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	390	387	386	395	560	555
		% change	-2.5	-3.3	-3.5	-1.3	-1.8	-2.6
14/03/16		Sample 2 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	383	380	383	366	525	535
		% change	-4.3	-5	-4.3	-8.5	-7.9	-6.1
14/03/16		Sample 6 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	390	382	382	370	530	535
		% change	-2.5	-4.5	-4.5	-7.5	-7	-6.1
14/03/16		Sample 7 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	378	378	378	366	528	530
		% change	-5.5	-5.5	-5.5	-8.5	-7.4	-7
14/03/16		Sample 4 Mesh Spacer	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	380	375	385	400	560	540
		% change	-5	-6.3	-3.8	0	-1.8	-5.3
14/03/16		Sample 6 Mesh Spacer	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	380	370	380	395	560	545
		% change	-5	-7.5	-5	-1.3	-1.8	-4.4
14/03/16		Sample 7 Mesh Spacer	400	400	400	400	570	570
02/06/16		Measurements after 5 washes	382	382	385	396	545	538
		% change	-4.5	-4.5	-3.8	-1	-4.4	-5.6

Measurements of marked fabric samples: distances between pairs of marks after 10 washes

Date	Time	Fabric	Top left to right	Ccentre left to right	Bottom left to right	Centre top to bottom	Diagonal top left to bottom right	Diagonal top right to bottom left
14/03/16		Sample 3 Polypropylene	400	400	400	400	570	570
02/06/16		Measurements after 10 washes	395	393	396	388	566	560
		% change	-1.3	-1.8	-1	-3	-0.7	-1.8
14/03/16		Sample 4 Polypropylene	400	400	400	-0.7	-1.8	570
02/06/16		Measurements after 10 washes	390	386	390	570	570	555
		% change	-2.5	-3.5	-2.5	-2.5	-1.8	-6.1
14/03/16		Sample 8 Polypropylene	400	400	400	400	570	570
02/06/16		Measurements after 10 washes	388	388	390	396	565	560
		% change	-3	-3	-2.5	-1	-0.9	-1.8
14/03/16		Sample 3 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 10 washes	380	375	379	365	526	526
		% change	-5	-6.3	-5.3	-8.8	-7.7	-7.7
14/03/16		Sample 4 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 10 washes	382	380	380	369	530	535
		% change	-4.5	-5	-5	-7.8	-7	-6.1
14/03/16		Sample 8 Texturised Nylon	400	400	400	400	570	570
02/06/16		Measurements after 10 washes	376	375	378	369	523	529
		% change	-6	-6.3	-5.5	-7.8	-8.3	-7.2
14/03/16		Sample 2 Mesh spacer	400	400	400	400	570	570
02/06/16		Measurements after 10 washes	373	365	375	400	546	536
		% change	-6.8	-8.8	-6.3	0	-4.3	-6
14/03/16		Sample 3 Mesh Spacer	400	400	400	400	570	570
02/06/16		Measurements after 10 washes	382	373	385	400	545	542
		% change	-4.5	-6.8	-3.8	0	-4.4	-4.9
14/03/16		Sample lost						

Measurements of marked fabric samples: distances between pairs of marks after 1 wash

Date	Fabric Polypropylene + Mesh Texturised Nylon + Mesh	Top left to right	Ccentre left to right	Bottom left to right	Left top to bottom	Centre top to bottom	Right top to bottom	Diagonal top left to bottom right	Diagonal top right to bottom left
15/8/16	Sample 1 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	385	385	386	393	393	393	562	559
	% change	-3.75	-3.75	-3.5	-1.75	-1.75	-1.75	-1.41	-1.93
15/8/16	Sample 5 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	396	395	396	388	391	391	564	556
	% change	-1	-1.25	-1.25	-3	-2.25	-2.25	-1.06	-2.46
15/8/16	Sample 9 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	393	393	394	391	392	391	561	562
	% change	-1.75	-1.75	-1.5	-2.25	-2	-2.25	-1.58	-1.41
15/8/16	Sample 2 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	394	395	398	388	392	392	559	559
	% change	-1.5	-1.25	-0.5	-3	-2	-2	-1.96	-1.96
15/8/16	Sample 6 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	395	395	398	387	386	391	564	561
	% change	-1.25	-1.25	-0.5	-3.25	-3.5	-2.25	-1.06	-1.58
15/8/16	Sample 7 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	395	396	398	391	392	389	561	563
	% change	-1.25	-1	-0.5	-2.25	-2	-2.75	-1.58	-1.23

Measurements of marked fabric samples: distances between pairs of marks after 5 washes

Date	Fabric Polypropylene + Mesh Texturised Nylon + Mesh	Top left to right	Ccentre left to right	Bottom left to right	Left top to bottom	Centre top to bottom	Right top to bottom	Diagonal top left to bottom right	Diagonal top right to bottom left
15/8/16	Sample 1 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	381	385	384	388	393	393	556	557
	% change	-4.75	-3.75	-4	-3	-1.75	-1.75	-2.46	-2.29
15/8/16	Sample 5 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	391	393	394	389	387	385	566	561
	% change	-2.25	-1.75	-1.5	-2.75	-3.25	-3.75	-0.71	-1.58
15/8/16	Sample 9 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	391	391	394	386	386	391	564	561
	% change	-2.25	-2.25	-1.5	-3.5	-3.5	-2.25	-1.06	-1.58
15/8/16	Sample 2 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	380	379	380	373	373	375	535	536
	% change	-5	-5.25	-5	-3.25	3.25	-6.25	-6.15	-5.87
15/8/16	Sample 6 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	380	381	385	374	377	378	540	539
	% change	-5	-4.75	-3.75	-6.5	-5.75	-5.5	-5.63	-5.44
15/8/16	Sample 7 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	381	383	390	378	376	381	546	541
	% change	-4.75	-4.25	-2.5	-5.5	-6	-4.75	-4.22	-5.09

Measurements of marked fabric samples: distances between pairs of marks after 10 washes

Date	Fabric Polypropylene + Mesh Texturised Nylon + Mesh	Top left to right	Ccentre left to right	Bottom left to right	Left top to bottom	Centre top to bottom	Right top to bottom	Diagonal top left to bottom right	Diagonal top right to bottom left
15/8/16	Sample 1 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	381	385	384	388	393	393	570	557
	% change	-4.75	-3.75	-4	-3	-1.75	-1.75	-2.46	-2.29
15/8/16	Sample 5 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	391	393	394	389	387	385	566	561
	% change	-2.25	-1.75	-1.5	-2.75	-3.25	-3.75	-0.71	-1.68
15/8/16	Sample 9 Polypropylene	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	391	391	394	386	386	391	564	561
	% change	-2.25	-2.25	-1.5	-3.5	-3.5	-2.25	-1.06	-1.58
15/8/16	Sample 2 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	380	379	380	373	373	375	535	536
	% change	-5	-5.25	-5	-3.25	-3.25	-6.25	-6.15	-5.89
15/8/16	Sample 6 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	380	381	385	374	377	378	540	539
	% change	-5	-4.75	-3.75	-6.5	-5.75	-5.5	-5.27	-5.44
15/8/16	Sample 7 Texturised Nylon	400	400	400	400	400	400	570	570
16/8/16	Measurements after 1 wash	381	383	390	378	376	381	546	541
	% change	-4.75	-4.25	-2.5	-5.5	-6	-4.75	-4.22	-5.09

Appendix G

Wrinkle recovery and pucker evaluation

Wrinkle recovery using AATCC test 128 standards. Evaluated by Moredun

Sample	Fabric	Rating 1-5
1	Polypropylene 1 1 wash	2
2	Polypropylene 5 5 wash	3
3	Polypropylene 9 10 wash	2
4	Cordura 2 1 wash	5
5	Cordura 6 5 wash	4.5
6	Cordura 7 10 wash	4.5

Pucker evaluation using AATCC standards

Sample	Fabric	Rating 1-5
1	Polypropylene 1 Warp stitching	4
1	Polypropylene 1 Warp binding	3
1	Polypropylene 1 Weft stitching	4
1	Polypropylene 1 Weft binding	3
2	Polypropylene 5 Warp stitching	5
2	Polypropylene 5 Warp binding	4
2	Polypropylene 5 Weft stitching	4
2	Polypropylene 5 Weft binding	4
3	Polypropylene 9 Warp stitching	5
3	Polypropylene 9 Warp binding	4
3	Polypropylene 9 Weft stitching	4
3	Polypropylene 9 Weft binding	4
4	Cordura 2 Warp stitching	5
4	Cordura 2 Warp binding	4
4	Cordura 2 Weft stitching	5
4	Cordura 2 Weft binding	4
5	Cordura 6 Warp stitching	5
5	Cordura 6 Warp binding	4
5	Cordura 6 Weft stitching	5
5	Cordura 6 Weft binding	4
6	Cordura 7 Warp stitching	5
6	Cordura 7 Warp binding	4
6	Cordura 7 Weft stitching	5
6	Cordura 7 Weft binding	4
7	Cordura warp webbing strip	4
8	Cordura weft webbing strip	3
9	Polypropylene warp webbing strip	1
10	Polypropylene weft webbing strip	1

Wrinkle recovery and pucker evaluation

Wrinkle recovery using AATCC test 128 standards. Evaluated by J&D Wilkie

Sample	Fabric	Rating 1-5
1	Polypropylene 1 1 wash	2
2	Polypropylene 5 5 wash	1.5
3	Polypropylene 9 10 wash	1.5
4	Cordura 2 1 wash	4
5	Cordura 6 5 wash	4
6	Cordura 7 10 wash	3.5

Pucker evaluation using AATCC standards

Sample	Fabric	Rating 1-5
1	Polypropylene 1 Warp stitching	4.5
1	Polypropylene 1 Warp binding	4
1	Polypropylene 1 Weft stitching	5
1	Polypropylene 1 Weft binding	3.5
2	Polypropylene 5 Warp stitching	3.5
2	Polypropylene 5 Warp binding	3.5
2	Polypropylene 5 Weft stitching	4
2	Polypropylene 5 Weft binding	3
3	Polypropylene 9 Warp stitching	4.5
3	Polypropylene 9 Warp binding	3.5
3	Polypropylene 9 Weft stitching	4
3	Polypropylene 9 Weft binding	3.5
4	Cordura 2 Warp stitching	5
4	Cordura 2 Warp binding	3.5
4	Cordura 2 Weft stitching	5
4	Cordura 2 Weft binding	3.5
5	Cordura 6 Warp stitching	5
5	Cordura 6 Warp binding	3.5
5	Cordura 6 Weft stitching	5
5	Cordura 6 Weft binding	3
6	Cordura 7 Warp stitching	5
6	Cordura 7 Warp binding	4
6	Cordura 7 Weft stitching	5
6	Cordura 7 Weft binding	3.5
7	Cordura warp webbing strip	4.5
8	Cordura weft webbing strip	3.5
9	Polypropylene warp webbing strip	3
10	Polypropylene weft webbing strip	2.5

Wrinkle recovery and pucker evaluation

Wrinkle recovery using AATCC test 128 standards. Evaluated by Lesley Cherrie

Sample	Fabric	Rating 1-5
1	Polypropylene 1 1 wash	2.5
2	Polypropylene 5 5 wash	3
3	Polypropylene 9 10 wash	2.5
4	Cordura 2 1 wash	4.5
5	Cordura 6 5 wash	4
6	Cordura 7 10 wash	4.5

Pucker evaluation using AATCC standards

Sample	Fabric	Rating 1-5
1	Polypropylene 1 Warp stitching	4.5
1	Polypropylene 1 Warp binding	3.5
1	Polypropylene 1 Weft stitching	4.5
1	Polypropylene 1 Weft binding	3.5
2	Polypropylene 5 Warp stitching	4
2	Polypropylene 5 Warp binding	3
2	Polypropylene 5 Weft stitching	4
2	Polypropylene 5 Weft binding	3
3	Polypropylene 9 Warp stitching	4
3	Polypropylene 9 Warp binding	3
3	Polypropylene 9 Weft stitching	4
3	Polypropylene 9 Weft binding	3
4	Cordura 2 Warp stitching	4
4	Cordura 2 Warp binding	3.5
4	Cordura 2 Weft stitching	4
4	Cordura 2 Weft binding	3.5
5	Cordura 6 Warp stitching	4.5
5	Cordura 6 Warp binding	4
5	Cordura 6 Weft stitching	4
5	Cordura 6 Weft binding	3.5
6	Cordura 7 Warp stitching	4.5
6	Cordura 7 Warp binding	4
6	Cordura 7 Weft stitching	4
6	Cordura 7 Weft binding	3
7	Cordura warp webbing strip	4
8	Cordura weft webbing strip	3
9	Polypropylene warp webbing strip	1
10	Polypropylene weft webbing strip	2

Appendix H

Martindale abrasion resistance test results

Mesh Spacer	Test Intervals			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	80000	80000	80000	80000.0	80000.0	80000.0	80000.0	80000.0	80000.0
1 wash	80000	80000	80000	80000.0	80000.0	80000.0	80000.0	80000.0	80000.0
5 wash	82000	80000	80000	80666.7	80666.7	80666.7	80666.7	80666.7	80666.7
10 wash	82000	82000	80000	81333.3	81333.3	81333.3	81333.3	81333.3	81333.3

Texturised nylon	Test Intervals			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	1 million	1 million	1 million	1000000	0.0	0.0	0.0	1000000	1000000
1 wash	1 million	1 million	1 million	1000000	0.0	0.0	0.0	1000000	1000000
5 wash	1 million	1 million	1 million	1000000	0.0	0.0	0.0	1000000	1000000
10 wash	1 million	1 million	1 million	1000000	0.0	0.0	0.0	1000000	1000000

Poly - propylene	Test Intervals			mean	SD	%CV	SE	Lower Cl	Upper Cl
Unwashed	21000	21000	25000	22333.3	2309.4	10.3	1333.3	19666.7	25000.0
1 wash	11000	11000	12000	11333.3	577.4	5.1	333.3	10666.7	12000.0
5 wash	11000	11000	13000	11666.7	1154.7	9.9	666.7	10333.3	13000
10 wash	13000	12000	10000	11666.7	1527.5	13.1	881.9	9902.8	13430.5

Abrasion resistance test results using 12 Kilopascal load using the Martindale method.

SCALE: No Breakdown, fibres visible, fuzzy, wear, break

Mesh Spacer	**1,000**	**5,000**	**15 pics**	**20 pics**	**25**	**30**	**35 pics**	**40**	**50**	**60**	**70**	**80**	**Breakdown**
1	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	B	
2	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	B	
3	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	B	
4	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	B	
5	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	B	
6	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	B	
7	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy		82000
8	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	B	
9	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy		82000
10	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy		82000
11	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	B	
12	NB	NB	fibres	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy		82000
polypropylene													
1	NB	fuzzy	fuzzy	**B**									21000
2	NB	fuzzy	fuzzy	**B**									21000
3	NB	fuzzy	fuzzy		**B**								25000
4	NB	fuzzy	**B**										11000
5	NB	fuzzy	**B**										11000

6	NB	fuzzy	**B**										12000
7	NB	fuzzy	**B**										11000
8	NB	fuzzy	**B**										11000
9	NB	fuzzy	**B**										13000
10	NB	fuzzy	**B**										10000
11	NB	fuzzy	**B**										12000
12	NB	fuzzy	**B**										13000
Texturised Nylon													
1	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	Test stopped at 1 million test cycles for all samples
2	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
3	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
4	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
5	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
6	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
7	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
8	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
9	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
10	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
11	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	
12	NB	NB	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	

Appendix I Commercial Calf Jacket Test results

Maximum Force and elongation (extension): Commercial calf jacket

Commercial Calf Jacket SAMPLE	Condition	Direction	Maximum Extension	Maximum Load	Mean extension	Mean load
1	10 wash	warp	92	1187	Warp	
2	10 wash	weft	68	853	**85**	**1280**
3	10 wash	warp	77	1372	Weft	
4	10 wash	weft	49	839	**59**	**846**

Maximum Force: Commercial calf jacket

Commercial calf jacket warp	Maximum Force (Newtons)		mean	SD	%CV	SE	Lower Cl	Upper Cl
10 wash	1187	1372	1279.5	130.8	10.2	92.5	1094.5	1464.5

Commercial calf jacket weft	Maximum Force (Newtons)		mean	SD	%CV	SE	Lower Cl	Upper Cl
10 wash	853	839	846.0	9.9	1.2	7.0	832.0	860.0

Maximum elongation (extension): Commercial calf jacket

Commercial calf jacket Warp	Maximum extension (mm)		mean	SD	%CV	SE	Lower Cl	Upper Cl
10 wash	92	77	84.5	10.6	12.6	7.5	69.5	99.5

Commercial calf jacket Weft	Maximum extension (mm)		mean	SD	%CV	SE	Lower Cl	Upper Cl
10 wash	68	49	58.5	13.4	23.0	9.5	39.5	77.5

Martindale abrasion test: Commercial calf jacket

Abrasion resistance test results using 12 Kilopascal load using the Martindale method.

SCALE: No Breakdown, fibres visible, fuzzy, wear, break

Commercial calf jacket outer fabric	**1,000**	**5,000**	**15**	**20**	**25**	**30**	**35**	**40**	**50**	**60**	**70**		**Breakdown**
1	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	Wear		73000
2	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	Wear		73000
3	NB	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	Wear		73000

Commercial calf jacket Outer fabric	Test cycles			mean	SD	%CV	SE	Lower Cl	Upper Cl
10 wash	73000	73000	73000	73000	0.0	0.0	0.0	73000.0	73000.0

Commercial calf jacket lining fabric	**1,000**	**5,000**	**6**	**7**	**8**	**9**	**10**	**Breakdown**
1	NB	fuzzy	wear	wear	wear	wear	B	10000
2	NB	fuzzy	wear	wear	wear	wear	B	10000
3	NB	fuzzy	wear	wear	wear	wear	B	10000

Commercial calf jacket Lining fabric	Test cycles			mean	SD	%CV	SE	Lower Cl	Upper Cl
10 wash	10000	10000	10000	10000	0.0	0.0	0.0	10000.0	10000.0

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